POPULAR ASTRONOMY.

By the Word of the Lord were the Heavens made.

PLAINLY WORDED AND UNTECHNICAL IN LANGUAGE.
AMPLY ILLUSTRATED.

Issued Monthly, Except for July and August.
Subscription Price, $2.50 in Advance.

VOL. II.

1894-5.

EDITORS:

William W. Payne. Charlotte R. Willard.

Office of Publication:
Goodsell Observatory of Carleton College,
Northfield, Minnesota.
1895.

+392

CONTENTS BY NUMBERS.

SEPTEMBER.

Mars. *Frontispiece.* Plate I.
Mars. (Illustrated). Percival Lowell 1
On the care and cleaning of object glasses. J. A. Brashear 9
Suggestions to observers of variable stars. P. S. Yendell 12
Instruments for the photography of meteors for the Yale Observatory. (Plate II). W. L. Elkin 17
Variable stars. IX. (Illustrated). J. A. Parkhurst 18
The spectroscope and some of its applications. IV. The spectra of the elements. J. E. Keeler 20
Gegenschein observations. A. E. Douglass 29
Folk-lore astronomy. L. P. Venen 32
The Arago medal. (Plate III) 33
Planet notes and tables for September and October. H. C. Wilson 34
Practical suggestions 40
General notes 44
Book notices 48
Star chart for September. (Plate IV).

OCTOBER.

The region of Lacus Solis on Mars. Drawing by J. M. Schaeberle. *Frontispiece.* (Plate V).
The large sun-spot of August, 1894. (Plates VI, VII, VIII). H. C. Wilson 49
Mars—The polar snows. (Illustrated.) Percival Lowell 56
Putting in place and adjusting the object glasses of refracting telescopes. J. A. Brashear 57
The fixed stars. IV. W. H. S. Monck 60
The moon. III. (Illustrated). Wm. W. Payne 67
The region of Lacus Solis. (*Frontispiece*). J. M. Schaeberle 72
An easy way to make a noon mark. Edward Riggs 73
Groups of time stars for amateur astronomers. Edna Iliff and Lottie Waterbury 74
The polar snows and non-glaciation of Mars. J. R. Holt 78
Planet notes and tables for November H. C. Wilson 82
Practical suggestions 86
General notes 91
Bibliography of astronomy 96

NOVEMBER.

Mars. *Frontispiece.* Plate X.
Mars. Spring phenomena. Percival Lowell..... 97
Progress of astronomical photography. H. C. Russell..... 101
Hints for a small telescope. Flora E. Harpham..... 106
The fixed stars. V. W. H. S. Monck..... 108
Attempts to photograph the sun. (Plate XI). W. W. Payne..... 116
Recent observations of the satellites of Jupiter. William H. Pickering..... 121
The great red spot and other markings of Jupiter. E E. Barnard..... 129
Planet notes and tables for December. H. C. Wilson..... 132
Practical Suggestions..... 138
General notes..... 140
Publishers' notices..... 144
Star map for November. (Plate XII).

DECEMBER.

Jupiter. *Frontispiece.* Plate XIII.
The planet Jupiter. (Illustrated). G. W. Hough..... 145
The great photographic nebula of Orion, encircling the belt and theta nebula. (Plate XIV). E. E. Barnard..... 151
Mars: atmosphere. Percival Lowell..... 154
On the variable stars of short peroid. (Illustrated). P. S. Yendell..... 160
Observations of the transit of Mercury, 1894, Nov. 9-10..... 168
Progress of astronomical photography, H. C. Russell..... 170
Occultation of the Pleiades December 10-11. (Plate XV). H. C. Wilson..... 176
Planet notes and tables for January. H. C. Wilson..... 181
Transit of Mercury notes..... 185
Comet notes..... 189
Practical suggestions..... 189
General notes..... 191
Publishers' notices.
Star map for December 1894. (Plate XVI).

JANUARY.

The Astrolabe, *Frontispiece.* Plates XVII, XVIII.
Sirius in ancient times. T. J. J. See..... 193
The Astrolabe. (Plates XIX, XX). Margaret L. Huggins..... 199
On variable stars of short period. (Illustrated). Paul S. Yendell..... 202
Pronunciation of star names derived from the Arabic. Robert H. West. 209
Long period variables. (Illustrated). J. A. Parkhurst..... 215
Position of the earth's axis. (Illustrated). Orrin E. Harmon..... 219
Almanacs. R. W. McFarland..... 225
Planet notes and tables for February. H. C. Wilson..... 228
General notes..... 237
Bibliography of astronomy..... 240

FEBRUARY.

Orbits of comets 1894 and De Vico's comet. *Frontispiece.* Plate XXII.
Comet *e* 1894, and the lost comet of De Vico, 1844 I. H. C. Wilson..... 241
Nearer to the stars. E. E. Barnard..... 245
The study of physical astronomy—suggestions to students and amateurs. T. J. J. See..... 249

Mars. The canals I. Percival Lowell..... 255
The astrolabe. II. History. (Plates XXII, XXIII). Margaret L. Huggins 261
The spectroscope in astronomy. Taylor Reed..... 266
On variable stars of short period III. (Illustrated). Paul S. Yendell..... 269
Planet notes and tables for March. H. C. Wilson..... 275
Comet notes..... 279
Practical suggestions..... 280
General notes..... 283
Book notices..... 287

MARCH.

Search chart for Barnard's periodic comet. *Frontispiece.* Plate XXIV.
The study of physical astronomy—its place in our universities and colleges. T. J. J. See..... 289
A new determination of the Saturnian ball and ring system with the great Lick telescope. E. E. Barnard..... 295
The spectroscope in astronomy. Taylor Reed..... 297
Astronomical ephemerides. J. Morrison..... 301
Nova Aurigæ. E. E. Barnard..... 307
The astronomical program for 1895. C. A. Young..... 308
Progress of astronomical photography. H. C. Russell..... 310
Long period variables. (Illustrated). J. A. Parkhurst..... 316
Barnard's periodic comet 1884 II. (Plate XXIV). H. C. Wilson..... 321
Planet notes and tables for April. H. C. Wilson..... 322
Practical suggestions..... 329
General notes..... 330
Book notices..... 336

APRIL.

Mars—oases. *Frontispiece.* Plate XXV.
The study of physical astronomy—some points for beginners. T. J. J. See..... 337
Mars—oases. Percival Lowell..... 343
Laplace on the variation of latitude. Arthur B. Hancock..... 349
The photography of comets with notes concerning comet Rordame. W. J. Hussey..... 353
Almanacs. II. R. W. McFarland..... 358
On variable stars of short period. IV. Paul S. Yendell..... 362
Reflectors. D. W. Edgecomb..... 366
The climate of Mars. Marsden Manson..... 371
Planet notes and tables for May. H. C. Wilson..... 374
Practical suggestions..... 383
General notes..... 383

MAY.

Nathaniel Bowditch. *Frontispiece.* Plate XXV*a*
The services of Nathaniel Bowditch to American astronomy. T. J. J. See..... 385
The Lowell observatory and its work. (Plates XXVI, XXVII, XXVIII) A. E. Douglass..... 395
The spectroscope in astronomy. Taylor Reed..... 402
The solar ephemeris. (Illustrated). J. Morrison..... 406
Long period variables. (Illustrated). J. A. Parkhurst..... 415
Making astronomy popular. Mary Proctor..... 418

Planet notes and tables for June. H. C. Wilson 419
Comet notes 424
Practical suggestions 425
General notes 426
Book notices 432

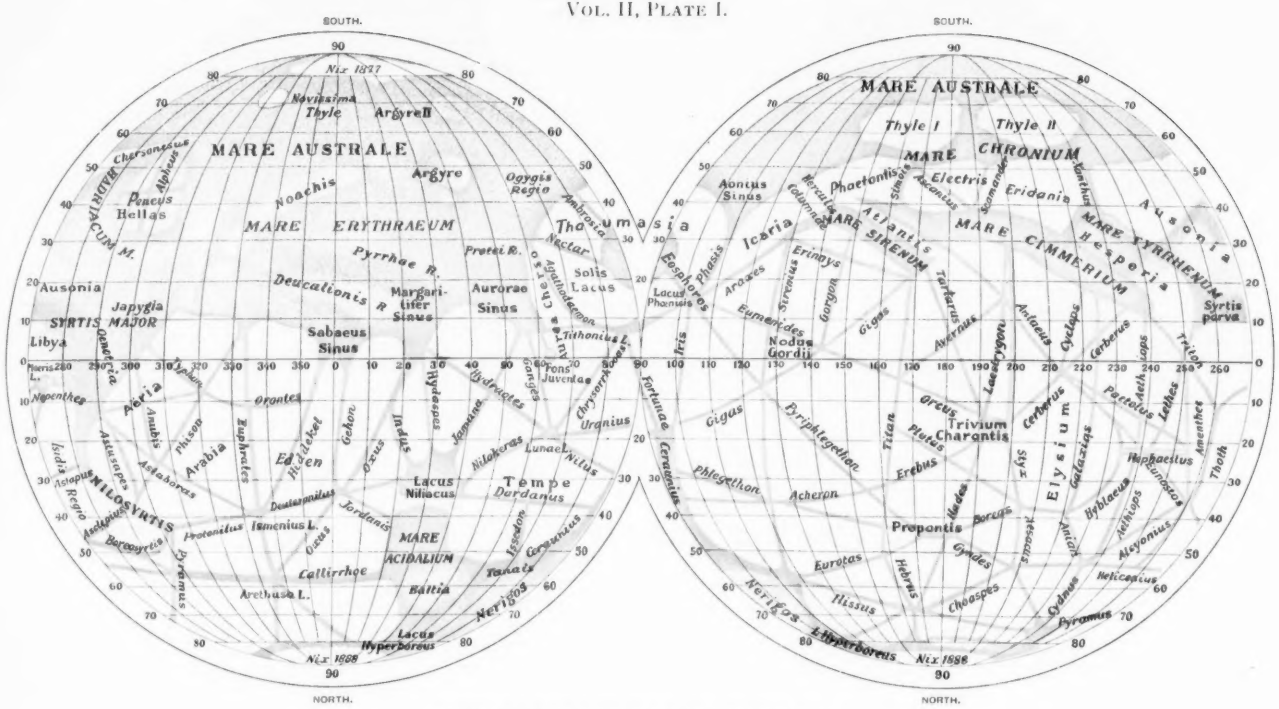
JUNE.

Micrometrical measures of the south polar caps of Mars. (Plates XXIX and XXX.) E. E. Barnard 433
Spectroscopic observations of Saturn at the Allegheny observatory. J. E. Keeler 443
Comet Rordame. II. (Plate XXXI.) W. J. Hussey 445
The lunar eclipse of March 11th, 1895. L. A. Eddie 449
Almanacs. III. R. W. McFarland 452
Popular astronomy as a supplement to the elementary text book 456
Progress of astronomical photography. H. C. Russell 457
Planet notes and tables for July and August. H. C. Wilson 464
Practical suggestions 470
General notes 471
General index of vol. II, with title page and index by months.

ILLUSTRATIONS.

Schiaparelli's map of Mars, 1888, Plate I, facing page 1
Drawings of Mars by Huyghens, Fig. 1 3
Drawings of Mars by Hooke, Fig. 2 3
Orbits of Mars and the Earth, Fig. 3 5
Instrument for the photography of meteors for the Yale observatory, Plate II, facing 17
5190 R Camelopardalis, 4847 S Virginis, 5338 V Boötis 19
Arago gold medal, Plate III, facing 33
Reflections from a plane mirror 33
The orbits of the satellites of Mars 38
Diagram showing the course of the Moon by the Earth's shadow during the partial eclipse, Sept. 14, 1894 39
Chart of the total eclipse of the Sun, Sept. 28, 1894 40
Eruptive solar prominence, Figs. 1, 2 45
Visualizing the Earth's motion 46
Map of the constellations visible Sept. 15 at 9 P. M., Plate IV, following 48
Drawings of Mars (nine views), Plate V, facing 49
Great sunspot group of August, 1894, (six views), Plates VI, VII, VIII, facing 50, 51, 52
Chart of the south pole of Mars 56
Drawing of Mars' south polar snow cap 56
The paths of the Earth and the Moon for October, 1894 70
An easy way to make a noon mark 73
Transit of Mercury 82
The satellites of Mars 84
Lightning flashes 89
Diagram showing the paths of Mercury across the Sun's disc during the transits of this century 93
Chart of small stars near Polaris 95
Small stars of Delphinus to 8th magnitude 96
Map of the constellations visible Oct. 15 at 9 P. M., Plate IX, following 96
Mars (two views) Plate X, facing 97
The coronagraph on Pikes' Peak, Plate XI, facing 120
Phases of the eclipses of Jupiter's satellites 134
Apparent orbits of the satellite of Neptune 137
Map of the constellations visible Nov. 15 at 9 P. M., Plate XII, following 144
Jupiter (six views), Plate XIII, facing 145
Satellites of Jupiter as seen by Galileo 1610 145
The great photographic nebula in Orion, Plate XIV, facing 153
Identification chart from the Durchmusterung 165
T Monocerotis and ζ Geminorum 166
Apparent course of the moon through the Pleiades group Dec. 10-11, 1894, Plate XV, facing 177
The satellite of Neptune 183
Mercury at egress 186

Map of the constellations visible Dec. 15 at 9 P. M., Plate XVI, following..... 192
The Astrolabe, Plates XVII, XVIII, XXIX and XX, facing.....193, 200, 201
Cygnus, Lyra and neighboring constellations..... 204
Aqui'a, Sagitta, etc..... 206
Sagitta..... 207
Neighborhood of X Cygni..... 208
3825 R Ursæ Majoris, 7118 X Aquilæ..... 215
320 U Cephei, 7085 R T Cygni..... 216
678 U Persei, 906 R Trianguli, 1805 V Orionis, 8324 V Cassiopeiæ..... 218
Position of the earth's axis (Figs. 1, 2, 3, 4)..... .....219, 220, 223, 224
Phases of the eclipses of Jupiter's satellites for December..... 230
Apparent orbit of the satellite of Neptune..... 232
Path of Encke's comet..... 234
Map of the constellations visible Jan. 15 at 9 P. M., Plate XXI, following..... 240
The orbits of comet *e* 1894 and De Vico's Comet 1844 I, Plate XXI*a* facing... 241
The Astrolabe, Plates XXII and XXIII, facing.....264, 265
Identification chart for U Aquilæ and Y Ophiuchi..... 271
Identification chart, δ Cephei and T Vulpeculæ..... 273
Phases of the eclipses of Jupiter's satellites for March..... 277
Object glass struck by lightning..... 286
Search chart for Barnard's periodic comet 1884 II, Plate XXIV, facing..... 289
103 T Andromedæ..... 317
7085 R. T. Cygni..... 319
3170 S Hydræ, 243 U Cassiopeiæ..... 320
Phases of the eclipses of Jupiter's satellites for April..... 325
Apparent orbits of the satellites of Uranus in 1895..... 327
Saturn's satellites..... 328
Mars—Oases (two views), Plate XXV, facing..... 337
The Sagittarius group of variable stars.....363, 364
Planets and the zodiac for May..... 375
Saturn's satellites..... 377
Phases of the eclipses of Jupiter's satellites for May..... 379
Apparent orbits of the satellites of Uranus in 1895..... 381
Dr. Nathaniel Bowditch, Plate XXV*a*, facing..... 385
Lowell observatory dome from southwest, Plate XXVI, facing..... 395
Lowell observatory shutter and windlass (two views), Plate XXVII, facing.. 396
Lowell observatory telescope mounting and observing chair (two views), Plate XXVIII, facing..... 397
Diagrams illustrating computations for the solar ephemeris.....407, 409, 410, 413
2815 U Geminorum..... 417
4492 Y Virginis and 7118 χ Aquilæ..... 418
Planets and the zodiac for June..... 420
Saturn's satellites.....e..... 422
South polar cap of Mars, 1892, Plate XXIX, following page..... 440
South polar cap of Mars, 1894, Plate XXX, preceding page..... 441
Comet Rordame July 13, 1893, Plate XXXI, facing page..... 448
Planets and zodiac for July and August..... 464


SOUTH.
NORTH.
MARE AUSTRALE
MARE ERYTHRAEUM
MARE CIMMERIUM
MARE TYRRHENUM
MARE CHRONIUM
Thaumasia
Ausonia
Hesperia
Elysium
Tempe
Lacus Niliacus
Lacus Hyperboreus
Nix 1877
Nix 1888
Novissima Thyle
Argyre II
Thyle I
Thyle II
Argyre
Noachis
Deucalionis R.
Margaritifer Sinus
Sabaeus Sinus
Aurorae Sinus
Solis Lacus
Pyrrhae R.
Pretei R.
Nectar
Ambrosia
Oggygis Regio
Aonius Sinus
Icaria
Phaethontis
Electris
Eridania
Atlantis
Lacus Phaenuis
Nodus Gordii
Tartarus
Cyclops
Cerberus
Syrtis parva
Japygia
SYRTIS MAJOR
Libya
Hellas
Peucus
Chersonesus Aphusa
CIMM. M.
Arabia
Aëria
Edom
Jordanis
Gehon
Indus
Euphrates
Phison
Astaboras
Nilosyrtis
Protenius
Ismenius L.
Arethusa L.
Callirrhoe
Baltia
Tanais
Nerigos
Acidalium
Mare
Hydriotes
Jamuna
Lunae Nilus
Nilokeras
Urganius
Chrysorrhoas
Fortunae
Cerauntius
Iris
Eosphoros
Phasis
Araxes
Erinnys
Gorgon
Eumenides
Gigas
Avernus
Antaeus
Lacus Lethes
Styx
Erebus
Acheron
Phlegethon
Pluto's
Trivium Charontis
Orcus
Titan
Briphlegethon
Propontis
Hades
Eurotas
Hebrus
Cnidus
Cheaspes
Tmolus
Pyramus
Ceraunius
Hyperboreus
Nerigos
Helicon
Alcyonius
Byblacus
Hiphaestus
Tithonius L.
Fons Juventae
Chersonesus
Ogygis Regio
Agathodaemon
Lacus Solis
Ausonia
Hesperia
Syrtis parva
Lethes
Tritonis
Amenthes
Thoth
Pactolus
Gelasius
Euxinus
Icarus
Sirenius
Scamander
Tanaïs
Ascanius
Borysthenes
Jordanis
Ismenius L.
Protenius
Astapus
Astasobras
Nepenthes
Orontes
Ophir
Amnis
Phison
Euphrates
Gehon
Indus
Jamuna
Hydriotes
Chrysorrhoas
Fortunae
Cerauntius
Lunae Nilus
Nilokeras
Urganius
Tempe
Dardanus
Gargarius
Ismenius L.
Jordanis
Mare
Acidalium
Callirrhoe
Arethusa L.
Baltia
Tanais
Nerigos
Lacus Hyperboreus
Nix 1888
Nix 1877
Novissima Thyle
Argyre II
Thyle I
Thyle II
Aonius Sinus
Icaria
Phaethontis
Electris
Eridania
Atlantis
Lacus Phaenuis
Nodus Gordii
Tartarus
Cyclops
Cerberus
Syrtis parva
Lethes
Tritonis
Amenthes
Thoth
Pactolus
Gelasius
Euxinus
Icarus
Sirenius
Scamander
Tanaïs
Ascanius
Borysthenes
Eosphoros
Phasis
Araxes
Erinnys
Gorgon
Eumenides
Gigas
Avernus
Antaeus
Lacus Solis
Ausonia
Hesperia
Agathodaemon
Nectar
Ambrosia
Oggygis Regio
Chersonesus Aphusa
CIMM. M.
Peucus
Hellas
Japygia
SYRTIS MAJOR
Libya

Popular Astronomy.

Vol. II. No. 1. SEPTEMBER, 1894. Whole No. 11.

MARS.

PERCIVAL LOWELL.

The editor of POPULAR ASTRONOMY has asked me to write a series of articles on what is now known of Mars together with what may become known about him, this autumn, during the coming opposition. As introductory I will preface a few words to the reader. One thing is, given the facts about our neighbor world, a person can form a better opinion as to what they disclose, than he might, in his modesty, suspect. For the problems which will present themselves for solution are questions of general physics in the first place, and questions of probability in the second. Especially is it a mistake to suppose that professional observers alone are entitled to an opinion on the subject. As a rule the professional observer is not much of a mathematician, nor of a physicist except of the journeyman kind, and though he is an expert in collecting data, he is often far from an expert in interpreting the same; as some of the comic theories advanced on the subject now before us seem to demonstrate. It may be well to remind the reader that neither Newton, Laplace, nor Gauss nor Helmholtz nor Lord Kelvin were observers. An observer may be an excellently good reasoner just as he may have blue eyes, or he may be a singularly poor one.

A second point is that no amateur need despair of getting interesting observations because of the relative smallness of his object-glass. There is much popular misapprehension on this point. In matters of planetary detail size of aperture is not the all-essential thing it is tacitly taken to be. There are three factors that enter into any observation: the observer, the atmosphere and the instrument; and, in matters of planetary detail both eye and air are more important than aperture. For an explanation why this is so optically, I will refer the reader to an article of mine in the August *Astronomy and Astro-Physics*, and to other articles which will appear later in the same periodical. Practical proof of this fact is afforded everywhere by the history of astronomical research. That Schiaparelli made his surprising discoveries on Mars with only an 8½-inch glass, that they were at first ridiculed by some, and that they had to wait years for

larger glasses to make them visible to common eyes are enough to hearten any amateur.

Next to the man is the atmosphere through which he looks. A large glass in poor air will not show what a small glass will in good air.

Once in about every twenty six and a third months a strange and startling visitant makes his appearance upon our midnight skies. To one who has not kept track of what the Greeks so suggestively called "the wanderers" (πλανητεο) this star will seem something of a portent. Outshining Sirius, dwarfing all other lights in those depths of space except the giant Jupiter himself, the stranger appears yet more fateful for being of a flaming red. This star is Mars, the planet of War of the ancients, which the Earth has once more overtaken in her swifter circling round the Sun.

But just as a soldier, sheriff or judge will thaw in the warmth of intimacy into something surprisingly human, so science has touched with satire the Martian superstition of olden times. Increasing acquaintance has now shown us that of the whole company of heaven the dread wanderer of War is probably the most peaceful body we know. Even in the hey-day of his *jeunesse orageuse* he was in all likelihood not extravagantly wild, and he has now long since lapsed into the quiet dotage of advancing years.

Disillusionment begins by actually daring to attack his hue. By means of the deadly parallel his flaming red is found to be perceptibly yellower than an ordinary gas-jet—a sad surprise to anyone who will take the trouble to hold a candle to his face. Some slight consolation, however, returns with the telescope for there he shows ruddier than to the naked eye.

Now there are two points of view from which we may regard any planet: as a member of our solar family and as a world in itself. It is principally in his second aspect that these papers will deal with Mars. For his relation to the rest of the system of which he forms a part is pretty well determined. It is his physical condition which still remains doubtful and to which modern astronomy is now especially directing its attention. His family standing is not unconnected with his individual state, inasmuch as each planet is busily engaged all the time in pulling all the others out of place; in consequence each is slowly deforming the other's orbits and by so doing changing the times and characters

of the seasons of their respective years, tending to produce glacial epochs and other interesting phenomena as the result.

But this relation of one planet to his fellows is chiefly interesting to us in the present connection not for what it effects but for what it allows us to infer. For the actual changes are brought about very slowly and do not sensibly affect the planet from one century to the next. On the other hand a knowledge of the relative conditions under which any planet performs his circuit about the Sun, as compared with those under which our own Earth makes her yearly round, is highly important to any understanding by us of that planet's physical state.

But instead of beginning with a more or less disconnected array of figures about Mars, I shall wait to let these introduce themselves in the places where they naturally belong, and shall take up a study of the planet where it really began at the eye-end of the telescope, thus giving the reader in this introductory paper some slight idea of what Mars looks like.

To start with then, we will begin with the first two drawings worthy of the name ever made of the planet by man.

FIG. 1.—DRAWINGS OF MARS BY HUYGHENS. Nov. 28, 1659, at 7 P. M. (Reproduced from Flammarion.)

FIG. 2.—DRAWINGS OF MARS BY HOOKE. March 13, 1666, at 12:40 A. M. (Reproduced from Flammarion.)

Now it would be safe to wager a small fortune that no one, not versed in the subject, would instantly recognize the pair for pictures of one and the same Martian marking. Yet such they are. The one was made by Huyghens in 1659, the other by Hooke in 1666, and both undoubtedly represent what is known as the Hour-glass Sea, the most distinctive and in a way the most important feature upon the planet. To explain the palpable discrepancy between its two delineations, we are led to consider the relative positions in space in which Mars and the Earth may find themselves.

The orbits of all the planets are approximately ellipses; if each planet were not perturbed by all the others, its orbit would be perfectly elliptical. This is no fortuitous coincidence, for given

the law of gravity it could not possibly be otherwise. The proof of this is one of the prettiest deductions in dynamics. To Kepler we owe the discovery that the planets move in ellipses, and to Newton the proof that this shows them to obey a central attractive force directed toward the Sun and varying inversely as the square of the distance from him. But these ellipses show something more. They show that although the Sun controls his family now, something other than the present Sun set the various members of it going originally. For had any of them not possessed some tangential motion to start with, at the time its individual existence began, it would simply have travelled straight into the Sun and thenceforward not travelled any more. The present elliptical orbits of the planets carry therefore in their very form proof of the truth of something like the nebular hypothesis of Laplace.

Now these elliptical orbits are chiefly interesting to us with regard to the subject in hand because they all differ in eccentricity, that is in the amount they deviate from a circle, which is but a special form of the ellipse. That of the Earth is fairly circular, a paltry three millions of miles summing up the difference between our nearest approach to the Sun and our farthest recession from him. But with Mars this is not the case; at times he is twenty-six millions of miles farther off from that luminary than he is at others. Now since the Earth and Mars take different periods of time to complete the circuits of their respective orbits, it will at once be seen that this brings them into conjunction at very varying distances apart. A diagram will make this clearer.

Now it so happens that the point of nearest approach between the orbits of the two planets lies opposite that part of the Earth's orbit which she reaches on August 25th and the farthest similarly opposite February 20th; so that the most favorable oppositions always take place in late summer or early autumn, while the least favorable take place in spring.

It also happens that the Martian summer solstice of the southern hemisphere occurs only 23 degrees distant from perihelion point. This makes it that in the most favorable oppositions Mars shows us chiefly his southern hemisphere; in the more distant ones his northern.

We are now in a position to reconcile the two drawings of Huyghens and of Hooke. For the one of these was made at the time of the summer solstice of the Martian southern hemisphere (like all astronomical drawings both are upside down), while the other was made during the winter solstice of the same hemi-

sphere. The latter is also properly represented the smaller for then the planet was much further off.

Now, innocent as it looks, Huyghens' drawing is perhaps the most important one of Mars that has ever been made. For from his observations of the spot it depicts, he was able to prove that Mars rotates on his own axis and to determine the time of that rotation. In other words he first learned the length of the Martian day.

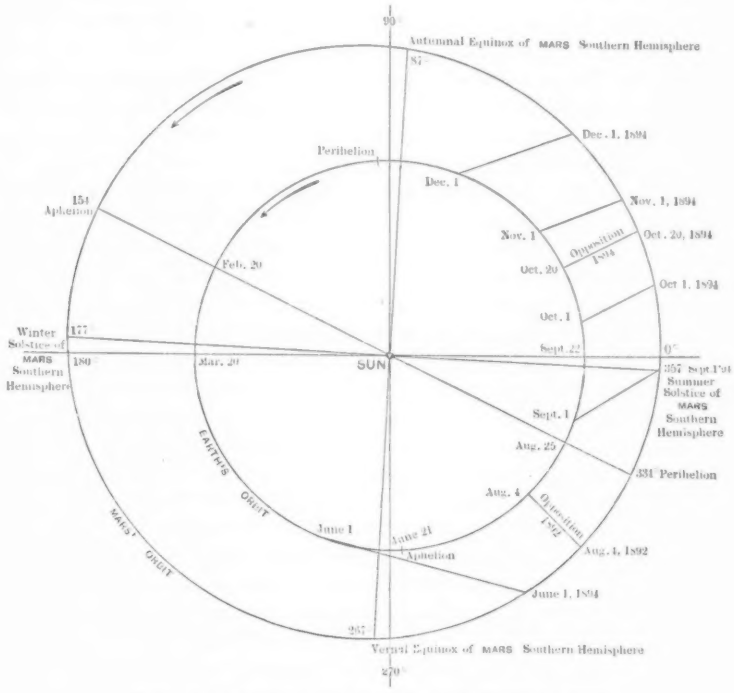


FIG. 3.—ORBITS OF MARS AND THE EARTH

FOR THE OPPOSITION OF 1894.

The importance of these earliest pictures of Mars has not lapsed with the lapse of time. By comparing Hooke's drawings and another by Huyghens in 1672 with modern ones, has been deduced a very accurate determination of the length of this Martian day (its sidereal day), a determination accurate to a tenth of a second. It amounts to $24^h\ 37^m\ 22^s.71$ (Proctor) or about 41^m longer than our own day.

We owe our knowledge of Martian time-keeping then to the distinctive marking known as the Hour-glass Sea. Its name was given it from its general appearance to that once familiar but now obsolete article. But interestingly enough it has acquired a title to the name in a yet more becoming manner, for it is, as we have just seen, by this hour-glass marking upon the planet's face that we have learned to tell the Martian hours across so many millions of miles of intervening space.

There is then, as Flammarion well says, a poetic fitness in keeping up this early appellative, instead of changing it to Syrtis Major, which Schiaparelli would have us do.

Before we part company with the orbits to pass on to other features of the disk, one more point connected with them is worth notice. If we draw a line from the Sun to the centre of Mars and pass a plane through the planet perpendicular to this line and to the plane of his orbit, this plane will divide the illumined half of him from the unillumined half. If now we draw another line from any point of the Earth's orbit to Mars' centre and pass a plane similarly perpendicular to that, it will cut off the hemisphere we see at any moment from the one we do not. As the two lines do not in general coincide, it will appear that in certain positions, in fact in all but two, Mars must present to us a face partly steeped in daylight, partly shrouded in night; in short that he shows gibbous like the Moon when she is between the half and the full. By drawing lines to more than one position occupied by the Earth it will be seen that this phase reaches a maximum when the Earth as viewed from Mars is at extreme elongation from the Sun, and that the amount of the phase at such time exactly equals the number of degrees of this elongation. For example on the sixteenth of last June the lacking lune amounted to 47°, that is the Earth was then evening star upon the Martian twilight skies and seemed to him 47° off from the Sun—about what Venus seems to us at her extreme elongation. It was some time after the invention of the telescope before astronomers began to see anything to speak of in Mars. More or less doubtful spots however were made out, and next to the discovery that the disk presented spots came the recognition of two curious white caps covering the planet's poles. These were sometimes seen together but more commonly not, owing to the tilt of the planet's axis. But about whichever pole happened to be bowed toward the Earth, the brilliant polar cap soon became under increasing optical aid a most conspicuous feature. Furthermore it was observed to vary with the Martian seasons. Through the winter of the

hemisphere to which it belonged, it was found to be very large, extending to about 45° down from the pole, that is it was 90° across. With the advent of spring it began to shrink till some two months and a half after the summer solstice it had dwindled to nearly nothing. Then with the deepening autumn it started once more to grow. It presented therefore almost precisely the same appearance viewed from the Earth that the Earth's polar snows would, viewed from Mars. It was in consequence taken to be really a polar snow-cap. The evidence that this is the fact is steadily accumulating, so that now, though we do not know the exact character of the snow, that it is snow in the widest meaning of the term is practically beyond a doubt. The evidence will be adduced when we come later to study the phenomenon in detail.

The rest of the disk was next found to be diversified by dark and light markings. The light ones were of an orange, the dark of a gray or greenish tint and the two were accordingly supposed to be land and water respectively. As the disk came to be better and better seen under increasing powers, it was evident that the proportion between the two was quite different from what it is on Earth. Instead of the water surface being largely in excess of the land, it appeared that the land area was in excess of the water.

The assumption that the light and dark markings represent land and water is doubtless largely correct. That the so-called land is land is next to certain. In the first place all the details of observation go to prove that it is such; secondly, the antecedent probabilities point in the same direction, and thirdly, no theory worth serious consideration has ever been advanced to show that it is not. That the "seas" are water is more doubtful. But the best evidence at present is that a part of the dark markings are really due to water while a part of them are not, betokening probably vegetation of some sort or other, as will appear later.

That these markings are essentially permanent is now beyond question. That is, unlike the markings on Jupiter and Saturn, those on Mars belong not to a cloud envelope but to the real surface of the planet. Yet as late as 1839 Mädler doubted this after having held the opposite view. Indeed the history of doubt about Mars is both humorous and instructive. It is really remarkable how correct first impressions have proved and how erroneous second thoughts; which means of course that Mars is much more like our Earth than we are altogether willing to admit.

To the ever "eagle-eyed" Dawes we owe much in the way of Martian topography as of most other astronomical matters. His observations in the early sixties made the basis of a chart of the planet by Proctor, the first important chart made. It was an admirable one in its day and although antiquated now may still be used advantageously for the general identification of the planet's topography. Later when influenced by Schiaparelli's growing importance he published a sort of compromise new edition of his chart,—the child of the closet, not of the Observatory—he made a bad botch out of an originally good business; for his new chart is neither good Dawes nor good Schiaparelli but something Mars never looked like to any mortal eye.

But of what we may call the middle period of our knowledge of Mars' markings, the admirably artistic drawings of Green in 1877 are the most typical as they were also the last of any account. For at the very moment that Green was thus unconsciously embalming the old areography at Madeira, Schiaparelli at Milan was inaugurating the new.

It was in 1877 that Schiaparelli first saw his now world-famous *canalli* which have been generally translated canals and then generally begrudged the quality which the name implies. But it looks now as if this were going to prove another instance of the virtue of first thoughts over second ones. Of this more anon; our present purpose being merely topographical.

Schiaparelli made several charts of the planet, his last one being in 1888. I have here reproduced it with a few additional names from his earlier ones from the copy given by Flammarion in his thesaurus entitled "La Planète Mars." The map labors, of course, under the general difficulty inherent in the attempt to represent an undevelopable surface upon a flat one; the result here being that not a single piece of the chart resembles the actual presentation of any part of the planet at any time. If the observer, however, will take the trouble to plot the positions of the several markings upon a plain globe suitably divided into meridians and parallels and view that, he will by tilting it properly get a very fair idea of the surface the planet presents at any given epoch.

Throughout my subsequent papers I shall refer to this map constantly as to any similar geographical map of our own earth. Before the series is finished, however, I shall present a later one from observations at this Observatory.

LOWELL OBSERVATORY, August, 1894.

ON THE CARE AND CLEANING OF OBJECT GLASSES.

J. A. BRASHEAR.

So many possessors of telescopes write to me in regard to the care and cleaning of their object glasses that I think it will be of interest to the readers of POPULAR ASTRONOMY if I give them the benefit of a long experience. There has always been such a halo thrown around the object glass of a telescope that those who own good glasses dread to touch them, and indeed this has partly been the fault of the makers themselves.

In an article on the care of the telescope in the May number of POPULAR ASTRONOMY, copied from Mr. Gibson's Hand-book, there are some good suggestions, and some precautions, but I have more faith in any person who can use a telescope with ordinary intelligence than to say to him "On no account should the two glasses composing the objective be separated or taken apart by the amateur;" on the contrary I believe every one who owns and uses a telescope should be so familiar with his objective that he *can* take it apart and put it together just as well as the maker of it, and, as an objective must be taken apart after considerable use, particularly in moist climates, so as to clean between the lenses, I see no reason why the "amateur" or the professional should not be the person to do it.

The writer does not advise the use of either fine chamois skin, tissue paper, or an old soft silk handkerchief, nor any other such material to wipe the lenses, as is usually advised. It is not, however, these wiping materials that do the mischief, but the dust particles on the lenses, many of them perhaps of a silicious nature, which is always harder than optical glass, and as these particles attach themselves to the wiping material they cut microscopic or greater scratches on the surfaces of the objective in the process of wiping.

I write this article with the hope of helping to solve this apparently difficult problem, but which in reality is very simple.

Let us commence by taking the object glass out of its cell. Take out the screws that hold the ring in place, and lift out the ring. Placing the fingers of both hands so as to grasp the objective on opposite sides, reverse the cell, and with the thumbs gently press the objective *squarely* out of the cell onto a book, block of wood or anything a little less in diameter than the objective, which has had a cushion of muslin or any soft substance laid upon it. One person can thus handle any objective up to 12 inches in diameter.

Before separating the lenses it should be carefully noted how they were put together with relation to the cell, and to one another, and if they are not marked they should be marked on the edges conspicuously with a hard lead pencil, so that when separated they may be put together in the same way, and placed in the same relation to the cell. With only ordinary precaution this should be an easy matter.

Setting the objective on edge the two lenses may be readily separated.

And now as to the cleaning of the lenses. I have, on rare occasions found the inner surfaces of an object glass covered with a curious film, not caused directly by moisture but by the apparent oxidation of the tin foil used to keep the lenses apart.

A year or more ago a 7-inch objective made by Mr. Clark was brought to me to clean. It had evidently been sadly neglected. The inside of the lenses were covered with such a film as I have mentioned and I feared the glass was ruined. When taken apart it was found that the tin foil had oxidized totally and had distributed itself all over the inner surfaces. I feared the result, but was delighted to find that nitric acid and a tuft of absorbent cotton cut all the deposit off leaving no stains after having passed through a subsequent washing with soap and water.

I mention this as others may have a similar case to deal with.

For the ordinary cleaning of an objective let a suitable sized vessel, *always a wooden one*, be thoroughly cleaned with soap and water, then half filled with clean water *about the same temperature as the glass*. Slight differences of temperature are of no moment. Great differences are *dangerous* in large objectives.

I usually put a teaspoonful of ammonia in half a pail of water, and it is well to let a piece of washed "cheese cloth" lie in the pail as then there is no danger if the lens slips away from the hand, and, by the way, every Observatory, indeed every amateur owning a telescope, should have plenty of "cheese cloth" handy. It is cheap (about 3 cts. per yard) and is superior for wiping purposes to any "old soft silk handkerchief," chamois skin, etc. Before using it have it thoroughly washed with soap and water, then rinsed in clean water, dried and laid away in a box or other place where it can be kept clean. When you use a piece to clean an objective *throw it away*, it is so cheap you can afford to do so.

If the lenses are very dirty or "dusty," a tuft of cotton or a camel's hair brush may be used to brush off the loose material before placing the lenses in the water, but no pressure other than the weight of the cotton or brush should be used. The writer

prefers to use the palms of the hand with plenty of good soap on them to rub the surfaces, although the cheese cloth and the soap answers nicely, and there seems to be absolutely no danger of scratching when using the hands or the cheese cloth when plenty of water is used, indeed when I wish to wipe off the front surface of an objective in use, and the lens cannot well be taken out, I first dust off the gross particles and then use the cheese cloth with soap and water, and having gone over the surface gently with one piece of cloth, throw it away and take another, perhaps a third one, and then when the dirt is, as it were, all *lifted up* from the surface, a piece of dry cheese cloth will finish the work, leaving a clean brilliant surface, and no scratches of any kind.

In washing large objectives in water I generally use a "tub" and stand the lenses on their edge. When thoroughly washed they are taken out and laid on a bundle of cheese cloth and several pieces of the same used to dry them.

I think it best not to leave them drain dry, better take up all moisture with the cloth, and vigorous rubbing will do no harm if the surfaces have no abrading material on them, and I have yet to injure a glass cleaned in this way.

This process may seem a rather long and tedious one, but it is not so in practice, and *it pays*.

In some places objectives must be frequently cleaned, not only because they become covered with an adherent dust, but because that dust produces so much diffused light in the field as to ruin some kinds of telescope work. Mr. Hale of the Kenwood Observatory tells me he cannot do any good prominence photography unless his objective has a clean surface, indeed every observer of faint objects or delicate planetary markings knows full well the value of a dark field free from diffused light. The object-glass maker uses his best efforts to produce the most perfect polish on his lenses, aside from the accuracy of the curves, both for high light value and freedom from diffused light in the field, and if the surfaces are allowed to become covered with dust, his good work counts for little.

If only the front surface needs cleaning, the method of cleaning with cheese cloth, soap and water, as described above, answers very well, but always throw away the first and if necessary, the second cloth, then wipe dry with a third or fourth cloth, but if the surfaces all need cleaning I know of no better method than that of taking the objective out of its cell—always using abundance of soap and water, and keep in a good humor.

As this paper has already grown to larger proportions than in-

tended I will reserve instructions for putting the lenses in place and adjusting them for another article.

SUGGESTIONS TO OBSERVERS OF VARIABLE STARS.

P. S. YENDELL.

It is gratifying to note the signs of an awakening of interest, among our amateur observers, in this field of work; a field in which the laborers have up to the present been few, although it especially commends itself to the amateur of modest equipment, as the one best suited to his means, and in which he may most confidently hope to achieve results of value to science: for the encouragement of such, it may be said, that not only is at least nine-tenths of all the work now being done on the variable stars the work of amateurs, but that the acknowledged highest authority on the subject is himself an amateur.

Mr. John A. Parkhurst has given, in the pages of this periodical, full details of the processes of making and reducing observations by the method known, from its originator, who was the father of this branch of astronomy, as Argelander's; this method is the best, and in fact, practically the only one open to amateurs of the class above alluded to, to whom more particularly this paper is addressed.

No expensive equipment, nor any extended knowledge of mathematics is requisite for success in this field: given a good pair of eyes, a fair stock of patience, and sufficient facility in computing to reduce his observations, the observer can do much valuable work with the very simplest optical aid, or, in fact, with none at all.

With a field or opera-glass, and a good set of maps of the naked-eye stars, such as are to be had at a moderate price, the changes of almost all the variables of short period can be followed throughout, and the maxima of many of those of long period observed. Sawyer's revision of the star-magnitudes, from the equator to $-30°$ of declination (south), to the seventh magnitude inclusive, which is one of the most valuable works of its kind in existence, was made entirely from observations with a field-glass; and perhaps the best proof that can be adduced of the value of such observations, lies in the fact that in the course of this work, seven new variables were discovered.

In view of certain letters which have come to me from beginners

in this line of work, it has seemed to me that a few words of advice and caution, drawn from the results of some years of constant practical experience in this line of observation, calling attention on the one hand to the precautions that the observer should take, and on the other, to the pitfalls into which he is liable to fall, will do no harm, and may prevent much difficulty, disappointment, and discouragement.

The instrumental outfit, as intimated above, may be very simple; optical perfection, though of course most valuable, is not indispensable; a fair binocular is within the reach of most amateurs: if a telescope be used, valuable work may be done with any aperture, from two inches upward, using, of course, the lowest power that will do the work: an equatorial mounting, with roughly graduated circles, is of great value, and will double the observer's working capacity. My own instrument, which I consider to be nearly an ideal one for this work, is a 4½-inch refractor, made by John Clacey; it is mounted equatorially, with 8-inch finding circles divided to single degrees, and reading by pointers; this graduation is actually more useful for my purposes than if it read by verniers to 20″ as the large field employed, about two degrees, makes such pointing as can be done with these circles quite accurate enough for finding the desired region, and much time is saved by it. With this instrument in its present form, all my telescopic work has been done for more than three years with great ease and quickness, and to my entire satisfaction.

For charts, either Heis', Klein's, or Schurig's is good enough for the bright stars, and can be had at moderate prices: for the telescopic stars, recourse must be had to the Durchmusterung charts, or, if these are not accessible, charts may be plotted from the catalogues.

The mathematical knowledge requisite is of the slightest; a little algebra and trigonometry, and a very little analytic geometry, are very useful in the reduction and discussion of the observations, but even these are not absolutely indispensable. A certain amount of familiarity with the ordinary processes of drafting is useful, as beside the use of graphic processes employed in reductions and discussions, one frequently finds himself under the necessity of plotting his own charts, as above hinted.

The mental qualities that should be brought to this work are: an unbiased mind, free from all preconceived ideas of what ought to be seen; great patience; the power of sifting evidence, and deciding strictly in accordance with its indication; a habit of re-

serving one's judgment; and above all, that attribute known to old New England house-keepers, as "faculty," and to the world in general as "gumption,"—is invaluable.

For various reasons, a good number of stars should be kept under observation; in this way only can the mind be kept free from forecasting how particular stars are likely to behave, the thing above all others to be avoided.

It is best for beginners to keep to the observation of well-known variables, and those whose changes are well-marked, and offer no special difficulty in observation: and in view of their well-known proclivity to the selection of the most difficult and troublesome objects, when left to choose for themselves, they should, if possible, have their observing lists selected for them by those of more experience and knowledge of the work, with whom they should endeavor to keep in touch, both on this account, and for general advice and assistance. When their work becomes of real value, also, it is through the assistance of such older workers that a channel for publication will most readily be found; and it should be remembered that unpublished observations, no matter how careful and numerous, can be of no value to science.

In noting your observations, be careful to put down exactly what you see, no matter how you think things ought to look; in fact, at the risk of reputation, I here insist on the urgent necessity of avoiding all knowledge of what is to be expected; to allow yourself to be in the slightest degree influenced by any ideas of the sort is the very most vicious practice into which you can fall, and if indulged in in the least degree, will infallibly deprive your observations of all value.

There is no field of observation in which experience tells more than in this; and no original work in the way of examination of suspected stars should be undertaken before the eye has been trained and the judgment matured by at least a year of careful work (and all work should be careful; nothing is worse than a loose and hasty habit of making comparisons) on the better known variables; until such experience shall have been gained, such work can only result in a darkening of counsel by words without knowledge: examiners of such cases cannot be too careful and conservative in forming their opinions, nor too cautious in announcing such decisions when arrived at: it is better to withold such altogether, than to make announcements that may afterward have to be retracted. Sawyer's well-deserved reputation as a reliable and accurate observer depends largely upon his practice in this respect; in no case has he ever announced a star to be variable which has not afterwards been fully confirmed.

The beginner should not be disturbed if the value of the step, as found by him, should, as it probably will, disagree with that of other observers: this is so far a personal matter, that in any particular case, it is highly improbable that any two experienced observers will exactly agree: in general, however, the average value will, after a year or two of practice, differ little from one-tenth of a magnitude according to general experience.

With regard to the magnitude scale adopted, the most available would seem to be what is called the "historic" scale, which is that of the Durchmusterung, of Heis', the Uranometria Nova, Schoenfeld's Southern Durchmusterung, the Uranometria Argentina, &c.; this is the scale which has been generally accepted by the great body of astronomers, and reference to which is most readily understood: if any other scale be used, it should be so specified, with its relation to the historic scale.

Excepting in observing the stars of the Algol type, in no case should more than one observation be made of any star during the same evening; and it is only the stars of short period that need daily observations: those of long period should be observed only once in several days, no care being taken to space the observations regularly, rather the reverse. In observing the stars of Algol type, which is, however, too difficult and critical work for the beginner, generally speaking, every means should be used to prevent a knowledge of the exact time at which the minimum is to be expected, or that of the observations; the working list of these stars should be made out at least a month beforehand, with the times only given to within an hour or two; the observations should not be regularly spaced; on the whole, perhaps the best method is to have some one set your observing clock wrong by a considerable amount, of which a record should be kept, and applied as a correction, when the observations are reduced; of course the amount of such alteration should be unknown to the observer until the observations are concluded; if a sidereal clock be used, the time of observation may be taken from it, and afterward reduced to mean time. In my own practice with this class of observing, I habitually refrained from keeping the run of the clock, making my observation when I consider a suitable interval to have elapsed since the last comparison, and only noting the time when setting down my note of the observation.

Do not let it disturb you if your observations do not tally with those of others exactly; no man is infallible; observational errors are common to all, and are unavoidable; always report just what you consider yourself to have seen, without fear or favor, and leave the star to decide the difference.

The observation of stars whose redness exceeds 3.0 or 4.0 of Chandler's scale, should be avoided by beginners; such stars are extremely difficult of observation, and this difficulty increases with the intensity of the color: stars of from 7.0 to 10.0 of this scale are difficult and uncertain for the most experienced observers, and there seems to be no means known of materially lessening this difficulty; although they are tempting objects, their observation should be eschewed by persons of small experience.

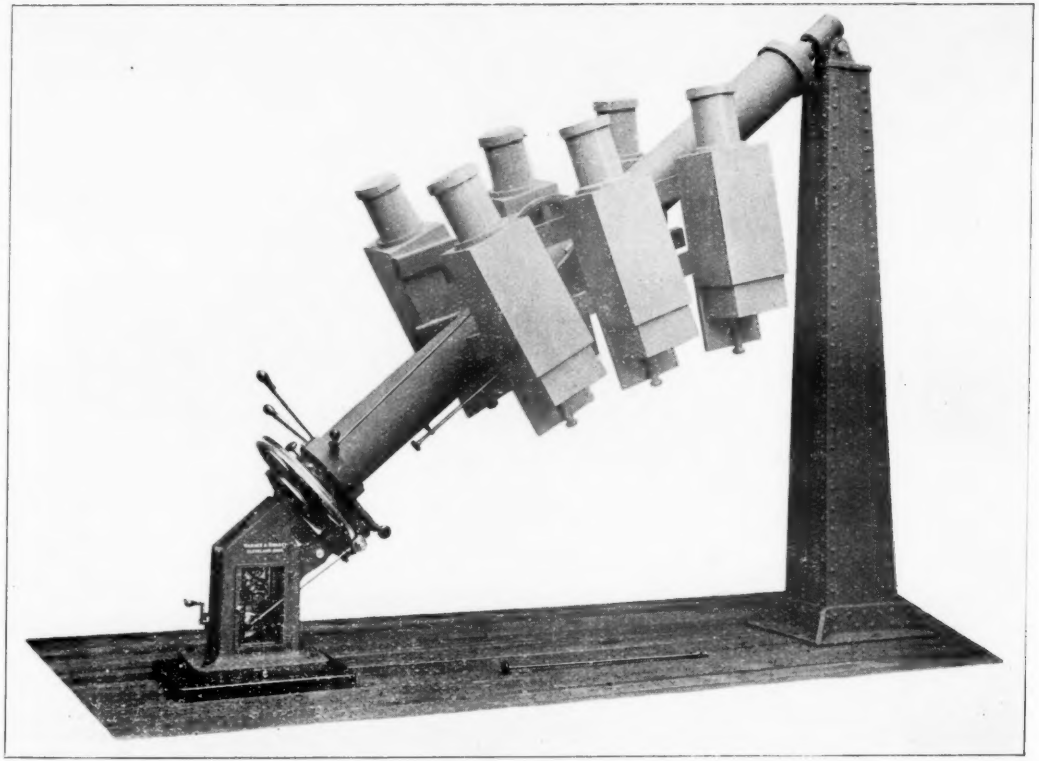
It remains to note the pitfalls, into which every observer is liable to fall, and which only constant care and watchfulness, and a habit of self-criticism, enable one to escape.

First, and probably most dangerous, is the influence of changing hour-angle, which affects the estimates of all stars of north declination: this is a physiological difficulty, depending on the local distribution of the sensitiveness of the retina of the eye, into which I have not space to go at length. It is perhaps sufficient to say by way of caution, that in comparing two stars by the Argelander method, the higher of the two will always appear fainter than its actual relative brightness, by an amount differing in every case, but which appears to be dependent upon the apparent distance between the stars, and the angle which the line joining them forms with that which joins the axes of the eyes: the most simple means of avoiding this source of error, is to select comparison-stars as nearly as possible on the same horizontal line with the variable, or to hold the head, in observing, so that the line of the eyes shall be as nearly as conveniently possible in a line parallel with that between the two stars, only avoiding a constrained position of the head, which would affect the observation.

For two cases of apparent annual variation, due to this influence, the reader is referred to the *Astronomical Journal*, Vol. XIV, p. 14.

Perhaps the next most serious danger is that due to atmospheric absorption; this decreases so rapidly as the star rises above the horizon, that at about an altitude of 25°, it may be practically said to have disappeared, for the purposes of this work; and may in general be avoided by refraining from observation at altitudes below 15° or 20° in cases of variables of low southern declination; however, it must be reckoned with, as it cannot be avoided, and varies quite unaccountably, from evening to evening; I have for more than a year been engaged in the examination of a list of suspected stars, from declination — 22° southward; and have found very few evenings during that time, when reliable observa-

PLATE II.



INSTRUMENT FOR THE PHOTOGRAPHY OF METEORS FOR THE YALE OBSERVATORY.

tions could be had; on one evening stars of the 11th magnitude could be easily held as far south as $-30°$, while on the next, to all appearance equally favorable for vision, stars of the 9th magnitude would be difficult objects as far north as $-15°$; the beginner, therefore, would do well to avoid stars of low southern declination.

The influence of moonlight is a considerable one, inducing apparent variation in a period of about four weeks, in many cases; this is so marked and well known a cause of error, that any announced variability having a period of nearly a lunar month, is looked upon with extreme suspicion, and at once examined for traces of this influence; only a single well-authenticated case of actual variability in such a period is known to exist, that of T Monocerotis: this influence is particularly observable in stars of a marked red color, such always appearing relatively brighter when observed in the presence of moonlight.

Between these three causes of error, all cases of periodicity of a day, month, or year, are open to strong suspicion, and would only be accepted after the most rigid and searching examination by known experts.

In conclusion, I would strongly insist on the necessity of careful, deliberate, and conscientious work; and that the beginner remember that quality is of infinitely greater importance than quantity; that a single well and thoroughly determined fact is worth more than pages of hurried and half-digested observations. It is due to a careful regard to this cardinal principle, that the names of Argelander, Gould, Schoenfeld, Chandler, and Sawyer, observers in this line of work, are known throughout the scientific world as the names of men whose statements may be implicitly accepted, with the full confidence that they will be borne out by the facts. Such a reputation is of unspeakably higher value than one based on no matter how great a quantity of crude and hasty work, and half considered deductions.

DORCHESTER, MASS., 1894, July 3.

INSTRUMENT FOR THE PHOTOGRAPHY OF METEORS FOR THE YALE OBSERVATORY.

W. L. ELKIN.

The experiments made at this Observatory last year seemed to show that if a sufficiently large field could be covered, it might be possible to secure quite a number of meteor tracks on photo-

graphic plates, during the August and December showers, at least. The incomparably greater accuracy, as against eye observations, with which these tracks locate the meteor and the radiant, has led us to consider the matter worth following up and accordingly application was made to the National Academy for an appropriation from the Lawrence Smith fund which is to be devoted to meteoric researches. From the grant awarded us the instrument represented in the cut has been constructed by Messrs Warner and Swazey. It is a polar axis of the "English" form, this seeming to be the most convenient and the best adapted mounting for carrying a number of cameras, and admitting of long exposures without break. The axis is of tubular form, about 12 feet long, the ends being pivots working in bearings which are adjustable on their supports. The southern support, or base, contains the clock-work, the northern support is a column containing the driving weights, the connection being made by a cord passing under the floor. The declination axis carries arms on either end which serve as supports for the cameras. On the cut six dummy cameras are shown; it is not likely for the present, however, that we shall use more than four. Graduated aids and slow-motions for both coördinates are provided, and the clock-work has an electric control. The apparatus is now mounted here, and will be tried on the Perseids this year.

YALE UNIVERSITY OBSERVATORY.

VARIABLE STARS.

J. A. PARKHURST.

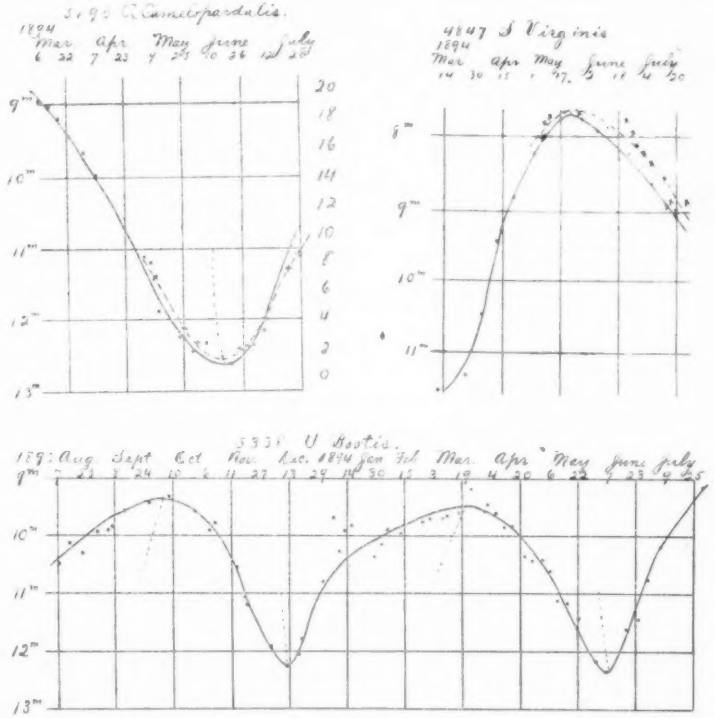
IX.

The accompanying curves will serve to illustrate the behavior of three variable stars.

5190 R Camelopardalis. The crosses represent the observations of Mr. W. Dearden of Trinidad, Colo., instrument used—a 9½-inch reflector. The broken line is the light curve, showing a minimum 1894 June 15. The dots are the observations of J. A. Parkhurst, instrument—a 6½-inch reflector. The curve drawn through these dots gives a minimum 12.6 magnitude June 14. The agreement between these two determinations of minimum is closer than would be expected.

In these figures the dates of observation are given in the horizontal line at the top, and the magnitudes in the vertical column

at the left. In the actual construction of the figures I have used the "light scale" (see Vol. I, p. 214) instead of the magnitudes. This light scale is deduced from the observations and is laid off in the vertical column on the right of the figure for 5190. The unit of the light scale is the "step." This scale can be expressed in magnitudes if the magnitudes of two or more of the comparison stars can be ascertained. To find the point of maximum or minimum, bisect the horizontal chords and produce the line of centers till it intersects the curve. The dotted lines show this operation.



4847 S Virginis. The crosses and broken line represent the observations of Mr. F. F. Arnold of Rockford, Ill., instrument—a 5-inch refractor. The date of maximum, deduced from Mr. Arnold's observations, is 1894 May 25. The dots and full line show the observations of J. A. Parkhurst, giving a maximum of 7. 8 mag. May 22. Here again the agreement is satisfactory.

5338 U Boötis. The curve shows the variations of this star

for the past year ,during which time it has passed two maxima and two minima. The dates are as follows :—

	Max.	Mag.	Min.	Mag.
1893	Oct. 4	9.3	1893 Dec. 12	12.2
1894	Mar. 21	9.5	1894 June 9	12.3

The light curve near the maximum is quite flat so that the exact date of that phase is somewhat uncertain. On the contrary the minima are very sharply defined, so that the period can be deduced from them with accuracy. The observations are by J. A. Parkhurst.

A considerable amount of work with variable stars has been done during the past summer by the above named observers and by Mr. W. E. Sperra of Randolph, Ohio. A more complete report will be given in the October number.

Attention is called to the article on Variable Star Observing in this number by Mr. P. S. Yendell. It is worthy the careful thought of every one who wishes to do good work in this line.

MARENGO, Ill., 1894, Aug. 7.

THE SPECTROSCOPE AND SOME OF ITS APPLICATIONS.

J. E. KEELER.

IV. THE SPECTRA OF THE ELEMENTS.

In a previous article describing the solar spectrum, I stated that many of the prominent dark lines are due to the absorptive action of the vapors of known metals, but I did not explain the nature of the relation between these dark lines and the bright lines which are obtained when the same metals are burned in front of the slit of the spectroscope. The relation is one of fundamental importance in spectrum analysis, but it has been explained at length in so many popular lectures and text-books that no great amount of space need be devoted to it here, although we cannot afford to pass it by without special notice.

Let us suppose that we are repeating Kirchoff's famous experiment. We place in front of the slit a calcium light, and observe that the spectrum is perfectly continuous, no lines of any kind being visible. We now introduce a sodium flame, such as we have used in former experiments, between the incandescent lime and the slit, and find that the spectrum is crossed by two dark lines in the yellow, at exactly the places where the bright lines of the sodium flame appear when the calcium light is removed; in other

respects its appearance is unchanged. It appears then, from this experiment, that the sodium flame is transparent to nearly all kinds of light, but that it is partially opaque to light of the same kind that it emits. It should be borne in mind that the dark lines are only *relatively* dark. The brightness of the sodium flame can in no way be diminished by placing the calcium light behind it; indeed, since the flame is *partially* transparent to its own kind of light, the dark lines are really brighter than the bright lines which are seen when the flame alone is in front of the slit. They appear dark by contrast, as the sun-spots appear dark by contrast with the more brilliant photosphere. The flame stops more light of these two wave-lengths from the incandescent lime than it emits. If the calcium light is dimmed, the dark lines become weaker, then vanish, and finally become bright on a less luminous continuous background.

Thus we see that the rays which a vapor readily emits are those which it strongly absorbs. If its emission is increased by raising its temperature, the absorptive power is increased in the same proportion. In order that the lines of a gas may be "reversed," *i. e.*, appear dark on a bright background, the temperature of the gas must be lower than that of the source which yields the continuous spectrum. The natural law which underlies all these phenomena was thus formulated by Kirchoff: "The relation between the power of emission and the power of absorption for rays of the same wave-length is constant for all bodies at the same temperature."

The strong absorptive action of sodium vapor on light given out by sodium vapor at a higher temperature can be shown by a simple experiment, which does not require elaborate apparatus, or even a spectroscope. If we place a bead of any common sodium salt in the flame of a Bunsen burner, so as to obtain a sodium flame as bright and hot as possible, and then hold in front of it the feebly luminous sodium flame of a spirit lamp, the latter will be outlined as a *dark* flame on the bright background of the flame of the Bunsen burner, although the difference of temperature in this case is not great enough to make the experiment a very striking one.

Many experiments of this kind have led to the following laws, by which we are enabled to interpret the appearances seen in the spectroscope. 1. A solid or liquid (or a sufficiently compressed gaseous body) when heated to incandescence gives a continuous spectrum. 2. A luminous gas under small pressure gives a bright-line spectrum. 3. An incandescent body whose light has passed through

a gas having a lower temperature than itself, gives a continuous spectrum crossed by dark lines, which occupy the same positions as the bright lines in the radiation spectrum of the gas.

These laws, which were determined by experiment, have a special significance when considered in connection with the kinetic theory of gases. According to this theory, the molecules of a gas are flying about in all directions with great velocity, continually colliding with one another, or with the walls of the vessel which contains them. If the interval between the collisions is comparatively large, the constituent atoms of a molecule can vibrate freely, in periods which are determined by their nature and by the way in which they are combined. To such vibrations are due the bright lines in the spectrum of a rarified gas. If, on the other hand, the molecules are practically in contact, as in a solid or liquid body or a gaseous body greatly compressed, the atoms no longer have a chance to execute their characteristic vibrations, waves of every length are communicated to the ether, and the resulting spectrum is continuous. The nature of the relation between absorption and emission is also readily understood. Just as one tuning-fork can take up the vibrations transmitted to it by the air from another tuning-fork, when both forks are in unison, but cannot do so if their periods are different, so an atom can take up the vibrations of the ether which synchronize with its own period, and thus deaden their intensity in the original direction, while it allows all other ether waves to pass unaffected. As both light and sound are the result of wave-motions in an elastic medium, we can generally find analogous phenomena in optics and accoustics. Such comparisons are very instructive, but it should be remembered that no analogies can be expected for such phenomena as depend upon the *direction* of the vibrations, as this is different in the two cases; the vibrations of light being transverse and those of sound longitudinal, or in the direction of propagation.

All these remarks would not, perhaps, be much to the point, if the spectroscope were still regarded as primarily an instrument of chemical analysis. It was thus considered by the pioneers of spectroscopy; but modern investigations have wandered farther and farther from the path that it was once supposed they would follow, and the interest which attaches to the study of the spectrum is now physical rather than chemical. By the chemist the spectroscope is almost unused; but the physicist has recognized the fact that the lines of the spectrum are the direct language of the atom and the molecule, and strange hieroglyphics as they are, he still manages to make out a part of the wonderful story which

they tell. From this point of view we shall regard the spectra of the elements, in considering them more closely; for the purposes of chemical analysis a mere catalogue of the characteristic lines would be sufficient.

It was once supposed that each element had its characteristic spectrum, which remained the same under all circumstances, and the simplicity of this view so commended itself to observers that the fact brought out by later investigations, that the same element can have several entirely different spectra, was accepted with some reluctance. In some cases the number of different spectra is considerable; thus, no less than five different spectra of oxygen are known. The changes mainly result from differences of temperature, and are undoubtedly the result of changes in the molecular structure of the element. It is reasonable to suppose that a complex molecular structure is attended by a complicated spectrum, and a simple molecular structure by a simple spectrum. On testing this view by experiment we find that the evidence of the spectroscope is generally in harmony with the teachings of chemistry although there are some exceptions.

If we examine the different elements with our spectroscope, we find the greatest diversity of spectra imaginable. Some spectra consist of but a few lines, and are obtained with the greatest ease; others contain many lines, sometimes distributed apparently at random, and sometimes in pairs or groups with exquisite precision. The yellow lines of sodium are obtained with extraordinary facility,—in fact it is difficult to obtain a spectrum in which they do not appear,—while some metals are vaporized with such difficulty that their spectra are obtained only with the aid of the electric spark.

As an instance of a sudden and complete change of spectrum we may take the case of the element nitrogen. When the ordinary spark from an induction coil is passed through a tube containing rarified nitrogen, a beautiful fluted spectrum is seen, consisting of a series of bands, each of which is bright and sharply defined on one side and fades away on the other. If, however, a Leyden jar is connected with the coil, so as to intensify the spark, the fluted spectrum vanishes, and in its place appears a spectrum of bright lines, superposed on a faint continuous spectrum which increases in brightness with augmented pressure. There is no indication in the appearance of the spectra that they belong to the same substance.

In some of the metals a gradual change takes place with increasing temperature; some of the lines brighten rapidly and new

lines appear, and although the spectra at extremes of temperature are quite different in appearance, all the intermediate steps of the process of transformation can be traced. In some cases the total change is not great. Iron has a spectrum containing hundreds of lines, which are nearly the same at different temperatures, the changes of relative brightness being comparatively small. It is hardly necessary to point out that all these changes are of great importance in their bearing on celestial spectroscopy.

The characteristic lines of an element are the lines which are strong and persistent through a great range of temperature. As the emission of the substance is strong for these wave-lengths at a low temperature, its absorption is also strong under the same circumstances, and hence these lines are easily reversed.

I have already mentioned those spectra in which the lines are rythmically ordered, evidently in accordance with some physical law which governs the vibrations of the atoms of the substance. On account of the importance of the inquiry to molecular physics, much attention has been given to the numerical relations of the wave-lengths in such a series of lines, with a view to discovering the law of atomic vibration, and many facts of the highest interest have been brought out. The idea which first naturally suggests itself is that the lines are analogous to the overtones of a musical note, like those which are produced by a vibrating cord harmonically divided; but an examination of the rates of vibration corresponding to the lines does not bear out this view; indeed as Kayser and Runge remark, the atomic vibrations rather resemble those of a plate or three-dimensional body than those of a stretched cord.

As the simplest example of a spectrum with rythmically or dered lines, let us consider the spectrum of hydrogen. The positions of five lines of the series are given in the figure representing the solar spectrum, in the third number of POPULAR ASTRONOMY.* If the reader will plat the lines C, F, Hγ, *h* and H on a separate slip of paper, or make them stronger on the map, he will see that the intervals between the lines progressively diminish in going toward the violet end of the spectrum. On the map the spacing of the lines is affected by the changing dispersion of the prism, and the rapid diminution of the intervals can be seen still better by platting the lines on the wave-length scale. The series extends however beyond the limits of the map, and it is an interesting fact, showing the dependence of one science on another, that

* The hydrogen line nearly coinciding with H of the solar spectrum is there erroneously called the fourth of the series; it is the fifth.

these upper lines were first discovered in the spectra of the stars, and afterwards obtained with terrestrial hydrogen. In some stars the sixteenth line of the series has been photographed, and at this point the interval between the lines is reduced to only six tenth-metres. A simple formula representing the wave-lengths of the lines in the hydrogen series with great exactness, has been given by Balmer.

The metals of the alkalies are especially suitable for spectroscopic investigation, first, because the chemical properties of these elements are well understood, and second, because the spectra are comparatively simple. The elements lithium, sodium, potassium, rubidium and cæsium form a well-known group, characterized by strikingly similar chemical properties which follow in degree the sequence of the elements as given in the list. It is therefore interesting to inquire whether these chemical relations are in any way represented by similarities of spectra.*

We may begin with sodium whose spectrum under ordinary conditions is already familiar to us. At the temperature of the alcohol flame, the visible spectrum consists of a single pair of yellow lines, but at higher temperatures other lines appear, and these lines are also arranged in pairs; moreover in the upper part of the spectrum, where the lines are least numerous, the pairs are arranged rythmically, like the single lines in the spectrum of hydrogen, although from the appearance of the lower spectrum it is evident that several series are mingled together. It is not possible to pick out the lines of each series by the eye, where the lines are numerous, but by computing a formula from observations of the lines which are evidently arranged in series the other lines belonging to it can be identified. In this way it has been found that the sodium spectrum is made up of three superposed series of pairs.

On investigating the spectra of the other metals of the group, we find that similar relations obtain. The lines of lithium fall in three series, but they are apparently single; the sodium lines are as we have seen double; the potassium lines are more widely double, and so on down the list, the lines of the cæsium pairs being quite widely separated. It seems likely therefore that the lithium lines are also double, although the components are too close to be separated. In each element the lines of corresponding series are situated farther and farther toward the red, as we go

* Most of the information contained in the rest of this article has been gathered from the admirable memoirs of Professors Kayser and Runge, in the transactions of the Berlin Academy of Sciences.

down the list, until when we come to caesium, the lowest pair falls in the infra-red where it cannot be seen; its place can however be calculated by the formula, and Professor Snow has actually found the lines, by their heating effect, as nearly in their calculated places as one could expect when the difficulty of the observations is considered.

That the lines of a series should satisfy a mathematical formula is a sufficiently striking proof that they are closely related in fact, but when we examine carefully the lines of any one series we find a close family resemblance which shows beyond all doubt that they really belong together, and in all probability have their origin in the vibration of the same atom. To one series belong all the characteristic lines of the element, and for this reason it has been called the principal series; the lines of each subsidiary series have also special properties. In the case of lithium, the lines of the principal series are sharp and easily reversed; those of the first subordinate series are greatly widened on both sides when much lithium vapor is present, and are generally reversed; while the lines of the second subordinate series broaden on the lower side only and are never reversed. All the lithium lines are included in these three series. The sodium pairs fall in three series, with the exception of a pair at λ 5675.9 and λ 5670.4, which differs from all others in the character of the lines, which are diffuse on the upper side. It is very probably the only visible member of a fourth series.

The discovery of these series in the spectra of the elements is evidently of great importance to celestial spectroscopy. If, for instance, we suspect that a certain line in the spectrum of a star is due to potassium, we look for other lines belonging to the same series, and if they are absent we may conclude that the apparent coincidence of the star-line with the line of potassium is merely accidental. Again, we may ask why it is that of all the sodium lines which have been mentioned only two pairs are found in the solar spectrum. This is a question that we can now readily answer. The pairs referred to are the well known D lines and a pair of lines whose wave-lengths are λ 3303.1 and λ 3302.5. Now these pairs both belong to the principal series, and they are the only lines of the series that fall where they can be recognized, the higher members being in the extreme ultra-violet among a great confusion of other dark lines. All the other sodium lines belong to the two secondary series. Their great tendency to widen indicates that molecules of some complexity, such as could exist only at comparatively low temperatures, are concerned in their origin, and

hence it is not surprising that they should fail to appear at the high temperature of the Sun.

Space does not permit us to consider at length the spectra of other groups of elements. We find in them pairs, triplets or other characteristic groups arranged according to a definite law, and also many lines which do not seem to be disposed systematically; but the lines whose spacing can be represented by a formula are generally the characteristic lines of the substance.

There is however one spectrum so remarkable that we must give it a little more than passing notice. Carbon is an element which is remarkable in chemistry for the vast number of compounds which it is capable of forming with other elements in consequence of its complex molecular structure. We might expect therefore to find its spectrum one of considerable complexity, and in this expectation we are certainly not disappointed. The spectrum, which consists of a number of bands whose sharp edges are turned toward the red, can be seen with a small instrument by holding the slit close to the blue flame of a Bunsen burner, but of course the spectrum obtained in this way is only a feeble one. By employing powerful apparatus, with the electric arc as a source of light, and especially by substituting the photographic plate for the eye of the observer, these feeble bands are resolved into fine lines, spaced with wonderful regularity. Toward the edges of the bands the lines are so closely packed that they can no longer be distinguished, and several sharp edges of inferior brightness are found in each band. Above the bright edges the lines become fainter and fainter, but according to Kayser and Runge they are still traceable, with sufficient exposure, until they meet the next band, so that no part of the spectrum is free from carbon lines, their total number being certainly over 10,000.

Let us examine more carefully one of these bands, say the one which begins at λ 3883.5. This is a band which does not appear in the spectrum of a Bunsen burner, although it is strong in the spectrum of the electric arc. Beginning at the sharp edge of the band and passing up the spectrum, we find that the lines, which at first were too close to be separately distinguished, begin to draw apart, the interval between them increasing gradually and with perfect regularity. Farther on they become double; but before the series can be traced very far (perhaps for 30 lines), a second sharp edge sets in, and with this begins a second series just like the first, so that beyond the second edge two independent series of lines with different intervals are superposed. Still farther on a third series begins, and then a fourth and a fifth, the result

being a wonderful confusion of lines, from which it is almost impossible, even with the aid of a formula, to pick out the lines of a given series. The other bands of the carbon spectrum have a quite similar structure, and some of them are still farther complicated by the occurrence of triplets in series, the intervals of the constituent lines and those of the groups varying progressively in accordance with some physical law.

Here I must close this imperfect account of the spectra of the elements. I have merely indicated the direction which recent spectroscopic investigations have taken. The facts already discovered are important, and promise still greater results in the future, for they have a direct bearing on the great problems of molecular physics.

I hope the beginner will not be disappointed when he finds that I have not told him how to recognize all the different elements by their spectra; the knowledge that will enable him to do this can be only in part obtained from books; the rest comes with long practice with the instrument. Lists containing the wave-lengths of the lines in the different spectra are of course indispensible and they may be found in Kayser's " Lehrbuch der Spektralanalyse " and in Watts' "Index of Spectra." The wave-lengths, based on early measures with imperfect instruments, are not very reliable but they are sufficiently accurate for ordinary purposes. A list of standard lines whose wave-lengths have been determined with extreme precision, has been published by Professor Rowland, and the more extensive lists of Professors Kayser and Runge are of nearly equal accuracy.

The pioneer observer Lecoq de Boisbandran published a book called "Spectres Lumineux," in two volumes, in 1874. One volume contains descriptive text, and the other beautifully engraved plates, representing different spectra as seen with an instrument of small dispersion. This book is very useful to possessors of small instruments, but I do not know how easily it can be obtained at present.

The spectra of most of the elements cannot be well exhibited without somewhat elaborate apparatus, but the characteristic lines of sodium, lithium, potassium, strontium, thallium, rubidium and some others are readily obtained by placing salts of these metals in the flame of a Bunsen burner. The spectrum of an ordinary arc light contains many bright lines, due to the metals present as impurities in the carbons. A beautiful fluted absorption spectrum is obtained by placing a few grains of iodine in a heated bottle held between the slit of a spectroscope and a bright

lamp-flame. An examination of these spectra will afford much pleasure and profit to the beginner.

GEGENSCHEIN OBSERVATIONS.

A. E. DOUGLASS.

Since the beginning of last month the following observations have been made on the Gegenschein and accompanying phenomena. The positions given below are from Heis' Zodiacal Atlas (epoch 1855). Each observation is accompanied by a record of the locality in which it was made and the approximate elevation of that locality above the sea. The numbers inserted in parenthesis immediately after, refer to the stations used in the examination of sites suggested for the Lowell Observatory. Observations without such numbers were made either at the railway station, hotel, or house of residence. Positions given invariably refer to the point of greatest brightness. A few abbreviations of obvious meaning are used.

1. March 5. Halstead, Kan. 1460 ft. $14^h\ 52^m$ G. M. T. R. A. 171°.0, Dec. + 2°.0, Diam. Nuc. 3°.5. Round, then fading gradually in all directions. Have never seen it at Blue Hill as easily as this. (Harvard Observatory observations, September-November, 1893).

2. March 6. Las Vegas, N. M. 6400 ft. $15^h\ 12^m$ G. M. T. R. A. 170°.4, Dec. + 3°.6, Diam. Nuc. 2°.5. Easily visible 6° from brightest point. Very easily seen for this time of evening.

3. March 6. Blanchard, N. M. 7070 ft. $16^h\ 32^m$ G. M. T. R. A. 168°.8, Dec. + 4°.3. Can stand on rear of moving train and easily observe Gegenschein. It is as bright as was usual in Arequipa (Harvard Observatory Observations, 1891-1893).

4. March 7. Benson, A. T. 3600 ft. $16^h\,02^m$ G. M. T. R. A. 171°.2, Dec. + 2°.7, Diam. Nuc. 2°.5, outer Diam. roughly 12°, probably elongated E. and W.

5. March 8. Tombstone, A. T. 4700 ft. $17^h\ 40^m$ G. M. T. R. A. 172°.8, Dec. + 5°.2, Diam. Nuc. 3°.7, outside Diams. N. and S. 10°, E. and W. 14°. Not so easily seen as last night.

6. March 9. Tombstone, A. T. 5070 ft. $17^h\ 44^m$ G. M. T. R. A. 172°.4, Dec. + 4°.5, Diam. 8°.0, elongated E. and W.

7. March 10. Tombstone, A. T. 4930 ft. $18^h\ 25^m$ G. M. T. Can see the same bright region east of Regulus (referring to region approximately R. A. 171° Dec. + 4°) but if that is not the

Gegenschein I can't tell where it is. Can trace zodiacal band across sky but not very easily. If 10 is the brightest I have ever seen it, its brightness now is 5.

8. March 11. Tucson, A. T. 2400 ft. $17^h\ 30^m$ G. M. T. Same bright region shows east of Regulus (approximately R. A. 171°, Dec. + 4°). Zodiacal band across sky shows 6 on scale of 10, passing near Præsepe, between α and η Leonis Majoris, and to Saturn.

9. March 22. Tempe, A. T. (7). 1400 ft. $14^h\ 55^m$ G. M. T. Observed zodiacal band from W. horizon to Leo Major but quite faint E. of Milky Way.

10. March 26. Phoenix, A. T. 1100 ft. $18^h\ 20^m$ G. M. T. R. A. 187°.2, Dec. — 5°.1, Diam. 3°.2. Gegenschein twice as bright as area so often observed recently.

11. March 29. Prescott, A. T. 5400 ft. $17^h\ 35^m$ G. M. T. R. A. 193°.0, Dec. — 3°.6, Diam. 4°.6.

12. March 31. Prescott, A. T. (9). 5700 ft. 15^h to 18^h G. M. T. Zodiacal light bright. Watched it carefully during the evening and there was no perceptible movement of apex of cone among the stars. The zodiacal band across the sky was quite noticeable when one took a general view of the Milky Way and was in general one-fourth as bright. Made no especial search for Gegenschein but think that its region was bright over extensive area.

13. April 1. Prescott, A. T. (9). 5700 ft. $16^h\ 05^m$ G. M. T. R. A. 194°.0, Dec. — 4°.8, Diam. 9°.1.

14. April 4. Flagstaff, A. T. (11). 7170 ft. 15^h to 16^h G. M. T. Zodiacal band across sky shows quite easily.

15. April 5. Flagstaff, A. T. (11). 7170 ft. $15^h\ 37^m$ G. M. T. Zodiacal band shows quite easily.

16. April 6. Flagstaff, A. T. (11). 7170 ft. $17^h\ 25^m$ G. M. T. R. A. 195°.7, Dec. — 7°.3, Diam. 7°.7. Gegenschein and zodiacal band easily seen.

17. April 7. Flagstaff, A. T. (12). 8180 ft. $16^h\ 55^m$ G. M. T. R. A. 198°.5, Dec. — 9°.0, Diam. 6°.0.

18. April 26. Flagstaff, A. T. (11). 7170 ft. $15^h\ 45^m$ G. M. T. Zodiacal band can be seen from W. horizon to Saturn but Gegenschein does not yet show well.

19. April 29. Flagstaff, A. T. (11). 7170 ft. $15^h\ 48^m$ G. M. T. R. A. 217°.0, Dec. — 14°.0, Diam. 8°.7.

20. May 3. Flagstaff, A. T. (11). 7170 ft. $16^h\ 19^m$ G. M. T. Zodiacal band shows brilliantly from W. horizon to Saturn but Gegenschein does not show well.

21. May 4. Flagstaff, A. T. (11). 7170 ft. $15^h\ 47^m$ G. M. T. R. A. 207°.7, Dec. — 9°.9, Diam. 4°.8. Zodiacal band bright from W. horizon to Saturn, decreasing gradually in intensity towards the east. If anywhere apex is in Cancer. (This position is some 15° from the point opposite the Sun and presumably has no value).

The following additional observations were made by Mr. E. Ronsie of Flagstaff, being the first work of this kind he has done. His point of observation has an approximate elevation above the sea of 6900 ft.

22. May 5. $19^h\ 07^m$ G. M. T. R. A. 217°.3, Dec. — 9°.3, Diams. E. and W. 12°, N. and S. 5°.

23. May 6. $19^h\ 20^m$ G. M. T. Two regions:—R. A. 218°.7, Dec. — 10°.0, Diam. 8°, and R. A. 208°, Dec. — 8°, Diam. 5°.

24. May 8. $20^h\ 10^m$ G. M. T. Band 4° or less in width, 2° N. of ecliptic, extending from R. A. 203° to R. A. 228°. Widest point at R. A. 213°.

25. May 9. $19^h\ 25^m$. G M. T. Two regions:—R. A. 230°, Dec. — 21°, Diam. 4°, and R. A. 212°, Dec. — 10°, Diam. 4°.

26. May 10. $19^h\ 40^m$ G. M. T. R. A. 228°, Dec. — 17°.5, Diam. 5°, and a band 3° wide from α to λ Virginis.

For the convenience of those who wish to make use of these observations I here insert the geographical positions of the various places mentioned above.

	h	m		°	′		h	m		°	′
Halstead, Kan.	6	30	W.	38	00	N.	Tucson, A. T.	7	24	W. 32	18 N.
Las Vegas, N. M.	7	01	"	35	30	"	Tempe, A. T.	7	28	" 33	28 "
Blanchard, N. M.	7	02	"	35	12	"	Phœnix, A. T.	7	28	" 33	28 "
Benson, A. T.	7	21	"	31	58	"	Prescott, A. T.	7	30	" 34	32 "
Tombstone, A. T.	7	20	"	31	40	"	Flagstaff, A. T.	7	27	" 35	12 "

It will be observed that when expressed in local time these observations are all rather early in the evening, which will explain the difficulty in seeing the Gegenschein in observations 18 and 20 and probably the large disagreement in observation 21.

The remarks under observation 12 have reference to a phenomenon observed several times in South America and in Cambridge, namely, a rapid westerly movement of the apex of the eastern zodiacal cone with reference to the stars, suggesting a large parallax. Several times this has been watched for in the western cone without success. Two observations made in South America have in general been confirmed; first, elevation of the observer above the sea has no noticeable effect except that at sea-level observations cannot be made so near the horizon; and second, the existence of a very thin haze in the atmosphere does not affect

the Gegenschein and kindred phenomena so much as it does the equally faint outlying portions of the Milky Way.

LOWELL OBSERVATORY, Flagstaff, A. T.
June 15, 1894.

FOLK-LORE ASTRONOMY.

L. P. VENEN.

The longevity of many quaint beliefs in regard to certain astronomical phenomena is passing strange.

If the old Grimalkinian adage were literally true, the alleged nine lives of a cat would not render Pussy any more tenacious of the tenure of life than are many of these crude notions.

During the last brilliant period of Jupiter I was showing its satellites to a mixed company of ladies and gentlemen.

My telescope was one of Alvan Clark's finest instruments of six inches aperture. The sky was exceptionally clear and the disc of the planet with three satellites was shown with splendid effect.

While the people were giving apt expression to their admiration over the beautiful spectacle, one lady of some professedly literary and scientific attainment made herself especially conspicuous. "O yes," she exclaimed, "I have often seen Jupiter's satellites in a looking-glass."

We were on the college campus and I sent a servant to the laboratory for a large heavy mirror. Holding it so all could catch a glimpse of the reflected image of the giant planet, there, surely enough, was the apparition of two brilliant points of light, one on either side of the primary orb.

It was in vain, however, that I tried to explain to Mrs. Bluestocking that the phenomenon was due to a well known optical illusion based upon the refraction and reflection of light. While she acknowledged that she could not see either one of the satellites with her unaided eyes, she persistently argued that the "innate magnifying power" of the mirror brought them into view! Nor was her enthusiasm abated in the least when I broke it softly to her that the mirror failed to show the satellites in the same positions relatively to their primary in which they were seen to be when viewed through the telescope.

As a last resort, I cited the fact that the planet Venus and the bright stars Sirius, Arcturus and Capella are accompanied by just such pseudo-satellites when reflected from a common looking-

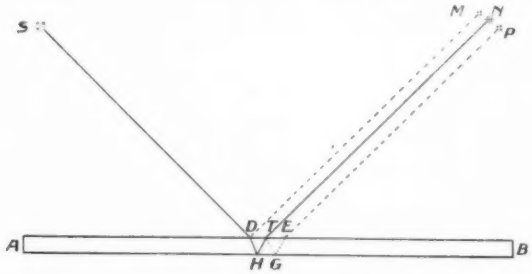
PLATE III.

ARAGO GOLD MEDAL.

POPULAR ASTRONOMY, No. 11.

glass, but that they were never seen when a plane mirror of polished metal was used.

The following diagram will serve to elucidate very clearly the presence of "Jupiter's satellites in a looking-glass."



Let AB represent an ordinary plane mirror and S the planet Jupiter.

The incident ray SD after a slight positive refraction will be reflected from the silvered surface of the mirror at H, in the direction HT, and thence after negative refraction to N, where will be seen the normal image of the planet bright and clear. A small portion of the light comprising the ray SD will be reflected at D from the outer or glass surface of the mirror to M, where will be seen a faint image of the planet, one of the alleged satellites.

Again the reflected normal ray HT, will suffer internal reflection from T to G, and thence from the silvered surface to E, whence after negative refraction it will proceed to P, where will be seen a second faint image or "satellite" of the planet.

It should be borne in mind that only a small portion of the normal ray HT suffers internal reflection at T.

THE ARAGO MEDAL.

It is thought that it would be instructive to the readers of POPULAR ASTRONOMY to see a fine plate showing the appearance and size of the Arago Gold Medal which was conferred on E. E. Barnard of Lick Observatory and Asaph Hall of Washington by the Academy of Sciences of France on the 18th day of December, 1893 (*Comptes Rendus*, No. 25, Dec. 18). To Professor Hall on account of the discovery of the satellites of Mars in 1877; to Professor Barnard because of his discovery of the 5th satellite of Jupiter. This medal has been conferred but once before, and that

was upon the illustrious Leverrier in recognition of his discovery of Neptune. The Arago Gold Medal was founded by the Academy of Sciences of France on the 14th of November, 1887, and its value is 1,000 francs, equalling in American money about $200. Professors Hall and Barnard each received a copy of the medal although conferred at the same time.

PLANET NOTES FOR SEPTEMBER AND OCTOBER.

H. C. WILSON.

Mercury will be at superior conjunction Sept. 2 and will be in poor position for observation during the two months. He will be in conjunction with Saturn Sept. 30 and with Uranus Oct. 14. He will be at greatest eastern elongation, 24° 31′ E. from the Sun, on the morning of Oct. 19. In the evening about this time Mercury, to northern observers, will set only a half hour after the Sun, so that it can be seen only in bright twilight. In the southern hemisphere the conditions for observation will be better.

Venus will remain "morning star" during these months, steadily approaching the Sun and growing fainter. She will be in conjunction with the Moon Sept. 27 and Oct. 27. On Oct. 9 at $10^h\ 56^m$ A. M. Venus will be just 7′ north of the star η Virginis, and on Oct. 29 at $10^h\ 07^m$ A. M. she will be 1° 06′ south of Saturn. Both however will be too close to the Sun to be easily seen.

Mars during these months will be in excellent position for observation. He will be at opposition Oct. 20. His distance from the Earth will then be about 40,500,000 miles, or about 5,000,000 miles greater than it was at the opposition of 1892. His declination, however, is 33° further north, so that for northern observers the planet is in very much better position than in 1892. Professor Pickering has already reported interesting observations of the surface markings of the planet, made at the new Lowell Observatory at Flagstaff, Arizona, and it is not too much to expect that more and better observations will be obtained this year than ever before. Mars is now in the constellation Pisces moving eastward. Sept. 15 he will turn the loop in his apparent course and begin retrograde (westward) motion, remaining in Aries and the corner of Pisces during the two months The reader will easily recognize Mars by the ruddy color and great brilliancy, this being the brightest object in the southeastern sky. Mars will be 7° south of the Moon Sept. 18 at $10^h\ 49^m$ A. M. and 5° 31′ south of the same on Oct. 15 at $6^h\ 31^m$ A. M.

Jupiter is the brilliant star one sees rising a little to the north of east soon after midnight. In October Jupiter will be in position to be observed a little before midnight. He will be at quadrature, 90° east from the Sun Sept. 28; at conjunction with the Moon Sept. 22 at $3^h\ 09^m$ and Oct. 19 $11^h\ 05^m$ P. M. Jupiter is in the feet of Gemini moving eastward, but will begin retrograde movement Oct. 24.

Saturn and *Uranus* will not be in position for observation, Saturn reaching conjunction with the Sun Oct. 21 and Uranus Nov. 7.

Neptune may be observed after midnight. He is in Taurus quite near the sixth magnitude star *l* Tauri.

Planet Tables for September and October.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
	h m	° ′	h m	h m	h m
MERCURY.					
Sept. 5	11 08.8	+ 7 12	5 38 A. M.	12 09.4 P. M.	6 41 P. M.
15	12 13.1	− 0 39	6 33 "	12 34.3 "	6 35 "
25	13 10.7	− 8 01	7 21 "	12 52.4 "	6 24 "
Oct. 5	14 04.2	− 14 23	8 01 "	1 06.4 "	6 12 "
15	14 53.0	− 19 20	8 57 "	1 15.7 "	5 59 "
25	15 29.6	− 22 05	8 43 "	1 12.9 "	5 43 "
VENUS.					
Sept. 5	9 35.6	+ 15 16	3 31 A. M.	10 36.5 A. M.	5 42 P. M.
15	10 23.5	+ 11 19	3 56 "	10 45.0 "	5 34 "
25	11 10.3	+ 6 50	4 22 "	10 52.2 "	5 23 "
Oct. 5	11 56.2	+ 2 01	4 48 "	10 58.9 "	5 10 "
15	12 42.0	− 2 57	5 13 "	11 05.1 "	4 57 "
25	13 28.3	− 7 51	5 40 "	11 12.0 "	4 44 "
MARS.					
Sept. 5	2 13.6	+ 9 29	8 30 P. M.	3 11.8 A. M.	9 53 A. M
15	2 16.0	+ 9 48	7 52 "	2 34.9 "	9 18 "
25	2 12.7	+ 9 45	7 10 "	1 52.3 "	8 35 "
Oct. 5	2 03.9	+ 9 23	6 23 "	1 04.3 "	7 45 "
15	1 51.6	+ 8 49	5 34 "	12 12.7 "	6 51 "
25	1 38.4	+ 8 15	4 44 "	11 20.1 P. M.	5 56 "
JUPITER.					
Sept. 5	6 12.2	+ 23 03	11 27 P. M.	7 09.8 A. M.	2 53 P. M.
15	6 17.7	+ 23 02	10 53 "	6 35.8 "	2 19 "
25	6 22.0	+ 23 00	10 18 "	6 00.9 "	1 43 "
Oct. 5	6 25.2	+ 22 59	9 42 "	5 24.7 "	1 07 "
15	6 27.1	+ 22 58	9 05 "	4 47.2 "	12 30 "
25	6 27.5	+ 22 59	8 26 "	4 08.4 "	11 51 "
SATURN.					
Sept. 5	13 27.8	− 6 43	8 51 A. M.	2 28.0 P. M.	8 05 P. M.
15	13 31.6	− 7 07	8 17 "	1 52.6 "	7 28 "
25	13 35.8	− 7 33	7 44 "	1 17.5 "	6 51 "
Oct. 5	13 40.2	− 7 59	7 11 "	12 42.6 "	6 14 "
15	13 44.8	− 8 26	6 38 "	12 07.7 "	5 38 "
25	13 49.3	− 8 52	6 05 "	11 32.9 "	5 01 "
URANUS.					
Sept. 5	14 39.5	− 15 10	10 38 A. M.	3 39.7 P. M.	8 42 P. M.
15	14 41.2	− 15 18	10 01 "	3 02.0 "	8 03 "
25	14 43.1	− 15 27	9 24 "	2 24.7 "	7 25 "
Oct. 5	14 45.2	− 15 37	8 47 "	1 47.3 "	6 47 "
15	14 47.4	− 15 47	8 11 "	1 10.3 "	6 09 "
25	14 49.8	− 15 58	7 35 "	12 33.3 "	5 32 "
NEPTUNE.					
Sept. 5	4 58.9	+ 21 13	10 23 P. M.	5 56.6 A. M.	1 30 P. M.
15	4 59.0	+ 21 13	9 44 "	5 17.4 "	12 51 "
25	4 59.0	+ 21 12	9 05 "	4 38.0 "	12 11 "
Oct. 5	4 58.7	+ 21 11	8 25 "	3 58.4 "	11 32 "
15	4 58.2	+ 21 10	7 45 "	3 18.6 "	10 52 "
25	4 57.4	+ 21 09	7 05 "	2 38.6 "	10 12 "
THE SUN.					
Sept. 5	10 57.9	+ 6 38	5 28 A. M.	11 58.5 A. M.	6 29 P. M.
15	11 33.8	+ 2 50	5 39 "	11 55.0 "	6 11 "
25	12 09.7	− 1 03	5 51 "	11 51.5 "	5 52 "
Oct. 5	12 46.0	− 4 56	6 03 "	11 48.3 "	5 33 "
15	13 22.8	− 8 43	6 16 "	11 45.8 "	5 16 "
25	14 00.6	− 12 17	6 29 "	11 44.1 "	4 59 "

Phases and Aspects of the Moon.

Central Time.

		d	h	m	
First Quarter	Sept.	6	7	03	P. M.
Apogee		10	2	12	A. M.
Full Moon		14	10	21	P. M.
Last Quarter		22	6	32	A. M.
Perigee		25	11	30	P. M.
New Moon		28	11	44	"
First Quarter	Oct.	6	1	01	"
Apogee		7	6	48	"
Full Moon		14	12	41	"
Last Quarter		21	12	56	"
Perigee		22	7	42	A. M.
New Moon		28	11	57	"

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

Alternate Minima.

		h	
Sept.	3	6	P. M.
	8	5	"
	13	5	"
	18	5	"
	23	4	"
	28	4	"
Oct.	3	4	"
	8	3	"
	13	3	"
	18	3	"
	23	2	"
	28	2	"

ALGOL.

Alternate Minima.

Sept.	5	4	P. M.
	13	10	A. M.
	17	4	"
	22	9	P. M.
	28	3	"
Oct.	4	8	A. M.
	10	2	"
	15	8	P. M.
	21	1	"
	27	7	A. M.

λ TAURI.

Alternate Minima.

Sept.	2	10	A. M.
	11	8	"
	19	5	"
	27	3	"

λ TAURI Cont.

		h	
Oct.	5	1	A. M.
	12	11	P. M.
	20	8	"
	28	6	"

R. CANIS MAJORIS.

Every third minimum.

Sept.	3	2	A. M.
	6	noon.	
	9	9	P. M.
	13	7	A. M.
	16	5	P. M.
	20	3	A. M.
	23	1	P. M.
	26	10	"
	30	8	A. M.
Oct.	3	6	P. M.
	7	4	A. M.
	10	2	P. M.
	13	11	"
	17	9	A. M.
	20	7	P. M.
	24	5	A. M.
	27	2	P. M.
	30	midn.	

S. CANCRI.

Sept.	2	6	P. M.
	12	6	A. M.
	21	6	P. M.
Oct.	1	5	A. M.
	10	5	P. M.
	20	5	A. M.
	29	4	P. M.

U OPHIUCHI.

Every fourth Minimum.

Sept.	3	10	A. M.
	6	7	P. M.
	10	3	A. M.
	13	noon.	
	16	8	P. M.
	20	5	A. M.
	23	1	P. M.
	26	10	P. M.
	30	6	A. M.
Oct.	3	3	P. M.
	6	11	"
	10	8	A. M.
	13	4	P. M.
	17	1	A. M.
	20	9	"
	23	6	P. M.
	27	2	A. M.
	30	11	"

Y CYGNI.

Every fourth minimum.

Sept.	4	9	A. M.
	10	9	"
	16	9	"
	22	8	"
	28	8	"
Oct.	4	8	"
	10	8	"
	16	8	"
	22	8	"
	28	7	"

Occultations Visible at Washington.

Date 1894	Star's Name.	Magnitude.	IMMERSION Washington M. T.		Angle f'm N p't.	EMERSION Washington M. T.		Angle f't N p't.	Duration.	
			h	m	°	h	m	°	h	m
Sept. 11	φ Capricorni	5½	5	48	12	6	27	311	0	39
13	70 Aquarii	6	6	21	19	7	09	288	0	48
13	Lalande 44734	7	9	04	46	10	25	239	1	21
18	47 Arietis	6	16	36	65	17	56	247	1	20
19	9 Tauri	7	8	02	10	8	27	307	0	25
19	23 Tauri	5	11	44	58	12	51	247	1	07
19	24 Tauri	8	12	19	48	13	27	256	1	08
19	η Tauri	3	12	21	53	13	31	251	1	10
19	B. A. C. 1171	8	12	59	28	14	10	276	1	11
19	27 Tauri	4	13	10	105	14	08	200	0	58
19	28 Tauri	6	13	10	86	14	20	219	1	10
23	ω^1 Cancri	6	14	05	13	14	13	358	0	08
23	ω^2 Cancri	6	14	02	98	15	02	273	1	00
25	26 Leonis	8	14	03	148	14	42	247	0	39
Oct. 6	B. A. C. 6628	6	10	23	121	11	04	197	0	41
8	χ Capricorni	5½	12	21	117	12	55	184	0	34
11	B. A. C. 8184	6	15	20	42	16	23	257	1	03
13	B. A. C. 221	6	6	24	64	7	29	227	1	05
13	70 Piscium	8	16	35	54	17	34	254	0	59
13	ε Piscium	4	16	53	83	17	48	227	0	55
15	27 Arietis	6	9	03	47	10	09	245	1	06
16	B. A. C. 1055	7	8	20	101	9	06	204	0	46
16	66 Arietis	6	10	28	42	11	34	258	1	06
17	χ Tauri	6	8	06	78	8	56	232	0	50
19	49 Aurigæ	6	10	37	73	11	34	275	0	57
19	54 Aurigæ	6	12	36	35	13	20	315	0	44
19	25 Geminorum	6	13	16	61	14	22	293	1	06
20	c Geminorum	6	13	10	146	13	51	223	0	41

Maxima and Minima of Variable Stars.

[From ephemerides by Dr. Loewy in the "Companion to the Observatory," and by Dr. Hartwig in the "Vierteljahrsschrift der Astronomische Geselischaft".]

MAXIMA.

Sept.	1	X Libræ.
	2	T Arietis.
	5	U Piscium.
	6	T Geminorum.
	7*	T Delphini.
	8	R Centauri.
	13	V Aurigæ.
	14	Y Capricorni.
	16	U Monocerotis
	16	T Aquarii.
	18	U Canis Min.
	18†	V Capricorni
	19	R Lyræ.
	20	S Leonis.
	29	S Carini.
	29	R Draconis.
	30	R Canum Ven.
	30	R Camelopardi
Oct.	1	S Vulpeculæ.
	4	W Libræ.
	4	R Orionis.
	4	S Orionis.
	5	R Reticuli.

MAXIMA CONT.

Oct.	8	S Camelopardi.
	12	T Virginis.
	13	S Aquilæ.
	13	R Arietis.
	14	V Leonis.
	14	W Leonis.
	16	W Herculis.
	17	W Tauri
	20	R Serpentis.
	21	W Capricorni.
	23	X Boötis.
	23	RR Virginis.
	25	R Scuti.
	26	R Sagittæ.
	26	S Geminorum.
	26	U Virginis.
	28	X Scorpii.
	31	U Monocerotis.

MINIMA.

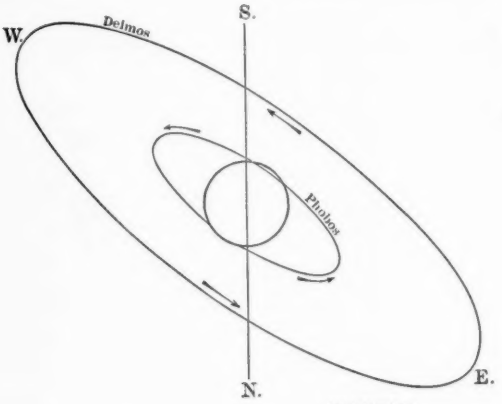
Sept.	4	R Lyræ.
	4	S Vulpeculæ.
	5	U Orionis.

MINIMA CONT.

Sept.	20	S Libræ.
	20	R Scuti.
	20	R Canis Min.
	22	R Trianguli.
	23	o Ceti.
	29	R Sculptoris.
	29	W Cygni.
Oct.	1	RT Cygni.
	2	R Piscium.
	6	U Boötis.
	10	X Capricorni.
	10	R Sagittæ.
	13	U Monocerotis.
	20	R Lyræ.
	22	R Vulpeculæ.
	22	R Persei.
	24	S Boötis.
	24	R Andromedæ.
	26	U Boötis.
	27	R Virginis.
	30	Z Cygni.

* The "Companion to the Observatory" gives this as Sept. 9.
† The "Companion to the Observatory" gives this as Sept. 22.

The Satellites of Mars.



DEIMOS.

Sept.	24	8.3	A. M.	W.	Oct.	18	5.8	" W.
	26	5.7	"	E.		20	8.6	" E.
	28	3.1	"	W.		22	11.4	" W.
	30	12.5	A. M.	E.		24	2.2	A. M. E.
Oct.	1	9.9	P. M.	W.		26	5.0	" W.
	3	7.3	"	E.		28	7.7	" E.
	5	4.7	"	W.		30	10.5	" W.
	7	2.1	"	E.		Nov. 1	1.3	P. M. E.
	9	11.5	A. M.	W.		3	4.1	" W.
	11	9.0	"	E.		5	6.9	" E.
	13	6.5	"	W.		7	9.7	" W.
	15	3.8	"	E.		9	12.5	A. M. E.
	17	1.2	"	W.				
	18	10.6	P. M.	E.				
	20	8.0	"	W.				
	22	5.5	"	E.				
	24	2.9	"	W.				
	26	12.3	"	E.				
	28	9.7	A. M.	W.				
	30	7.1	"	E.				

PHOBOS.

		h					h				h		
Sept.	24	4.6	A. M.	W.	Oct.	6	11.2	"	E.	Oct.	18	5.8	" W.
	25	7.4	"	E.		7	2.0	P. M.	W.		19	8.6	" E.
	26	10.2	"	W.		8	4.8	"	E.		20	11.4	" W.
	27	1.0	P. M.	E.		9	7.6	"	W.		22	2.2	A. M. E.
	28	3.7	"	W.		10	10.4	"	E.		23	5.0	" W.
	29	6.5	"	E.		12	1.1	A. M.	W.		24	7.7	" E.
	30	9.3	"	W.		13	3.9	"	E.		25	10.5	" W.
Oct.	2	12.1	A. M.	E.		14	6.7	"	W.		26	1.3	P. M. E.
	3	2.9	"	W.		15	9.5	A. M.	E.		27	4.1	" W.
	4	5.7	"	E.		16	12.3	P. M.	W.		28	6.9	" E.
	5	8.4	"	W.		17	3.0	"	E.		29	9.7	" W.
											31	12.5	A. M. E.

For Phobos the central time of every seventh eastern and western elongation is given, and for Deimos every third; the intermediate ones may be found by adding the periodic time of each satellite. Periodic time of Phobos $7^h\ 39^m.2$. Periodic time of Deimos $1d\ 6^h\ 17^m.9$

A Partial Eclipse of the Moon will occur on the night of Sept. 14, 1894. It will be visible throughout North and South America. The beginning will be visible in the western part of Europe and Africa. The accompanying diagram will give the reader some idea of the Moon's course as it passes by the Earth's shadow. The large shaded circle represents a cross-section of the Earth's shadow and the small circles represent the Moon at first and last contacts and middle of eclipse. The Moon will pass by the lower edge of the shadow, touching it first at the southernmost point. The observer will therefore see the shadow first at the north point of the Moon's disk. As the Moon moves up toward the left the shadow will appear to move down toward the right, covering at the middle of the eclipse a little less than a quarter of the diameter of the Moon's disk, and leaving it at a point 58° to the west from the north point. The first contact will occur at $9^h\ 36^m$, central standard time, the Moon's center being then at the point M. Before this a faint shading, due to the penumbra of the Earth's shadow, will have been noticed on the upper part of the disk. At $10^h\ 32^m$ the Moon will be at O, and the eclipse at its maximum. At $11^h\ 28^m$ the Moon will be at P

leaving the shadow at R. After that there will be only the faint penumbral shading on the west side of the disk.

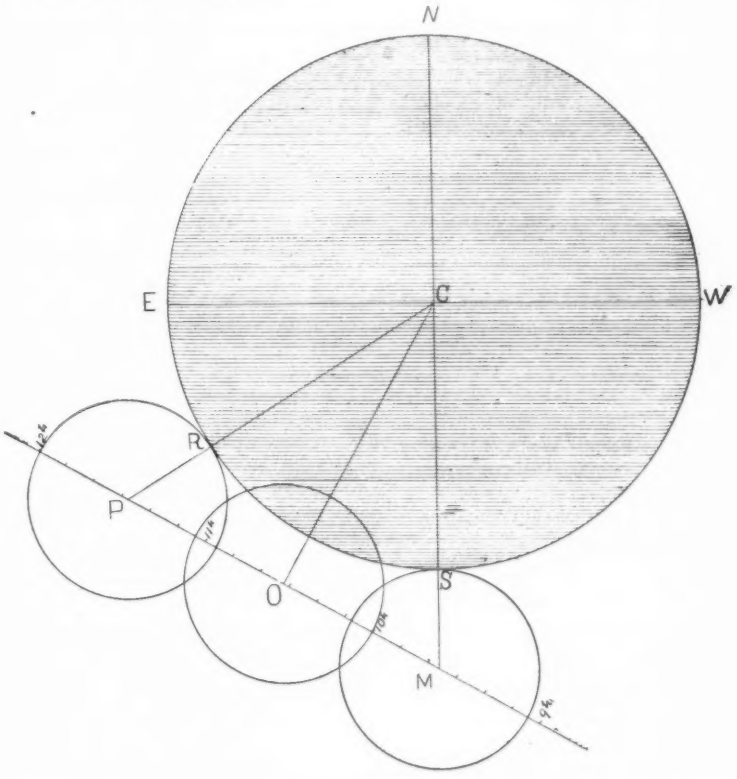


DIAGRAM SHOWING THE COURSE OF THE MOON BY THE EARTH'S SHADOW DURING THE PARTIAL ECLIPSE, SEPT. 14, 1894.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension Sept. 14, $15^h\ 35^m\ 42^s.8$.

Sun's right ascension	11^h	31^m	$36^s.20$	Hourly motion			$8^s.97$
Moon's right ascension	23	31	36 .20	Hourly motion		109	.98
Sun's declination	3°	04′	10″.0 N	Hourly motion	0′	57″	.8 S
Moon's declination	3	59	33 .5 S	Hourly motion	14	52	.6 N
Sun's equa. hor. parallax			8 .5	Sun's true semi-diameter	15	54	.9
Moon's equa. hor. "		55	24 .1	Moon's " "	15	05	.6

TIMES OF THE PHASES.

		h	m		
Moon enters penumbra	Sept. 14	7	58.6	P. M	Central Standard Time.
Moon enters shadow		9	35.6	"	
Middle of eclipse		10	31.6	"	
Moon leaves shadow		11	27.7	"	
Moon leaves penumbra	Sept. 15	1	04.4	A. M.	

A Total Eclipse of the Sun will occur Sept. 28, 1894. It will be invisible in America. The path of totality passes across the Indian Ocean as shown in the accompanying cut. The eclipse will be partial in Africa, Persia, Hindostan and

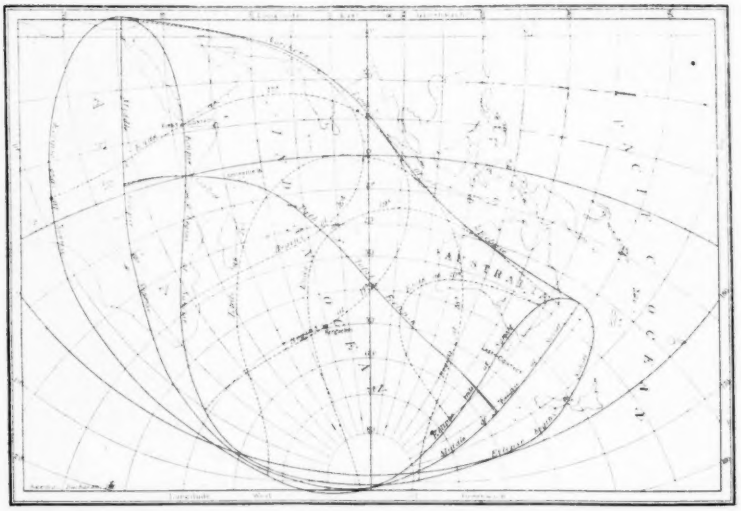


CHART OF THE TOTAL ECLIPSE OF THE SUN, SEPT. 28, 1894.

southern Australia. The times marked on the chart are expressed in Greenwich mean time.

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich M. T.		Longitude from Greenwich.		Latitude.	
	h	m	°	′	°	′
Eclipse begins..... Sept. 28	15	01.0	42	50.7 E.	11	49.2 N.
Central eclipse begins...	16	03.7	26	44.3 E.	1	47.1 N.
Eclipse at noon.....	18	06.2	86	01.3 E.	34	11.6 S.
Central eclipse ends.....	19	14.1	162	43.3 E.	56	24.9 S.
Eclipse ends.....	20	17.0	145	54.0 E.	46	24.1 S.

PRACTICAL SUGGESTIONS.

If you want to know, ask ; possibly somebody can answer. But remember that it is always easier to ask than it is to answer.

55. I notice what is said on page 335, March number of POPULAR ASTRONOMY, of a correspondent failing to see the companion of Polaris with a 3½-inch glass and power of 160. I can see it with my glass and power of only 31. I can put a stop on and cut the aperture down to two inches and yet easily see it with same power. W. E. S.

RANDOLPH, Ohio.

56. What is a telescope of the "Comet-seeker" form? W. E. S.

Answer. The comet-seeker is a telescope usually varying from 4 to 10 inches in aperture suited to the tastes or wishes of the owner. Such an instrument carries a low power (30 to 50) and a large field eye-piece (50′ to 90′), which are necessary for comet sweeping. A reflector mounted so as to sweep vertically and parallel to the horizon is the most convenient form. Mr. J. A. Brashear makes a very good instrument of this kind at a reasonable price. Mr. Denning's book entitled "Telescopic Work for Starlight Evenings" gives excellent instruction for comet seekers.

57. Please explain the table of Auxiliary Quantities for computing Precession found on page 87, January number of *Astronomy and Astro-Physics.* W. E. S.

Answer: This may perhaps be best explained by means of an example. Suppose we wish to reduce the place of the star No. 14401 in Lalande's catalogue to the beginning of the year 1894. The right ascension (α_0) of the star, for the year 1800, is $7^h\ 13^m\ 57^s.27$, and the declination (δ_0) $+\ 39°\ 03'\ 09''.7$. Lalande gives the annual precession for 1800 as $+\ 4^s.199$ in R. A. and $-\ 6''.36$ in Decl. We may use these to reduce the R. A. and Decl. to the middle epoch 1847. Multiplying $4^s.199$ and $6''.36$ by 47, gives us $3^m\ 17^s.35$ to be added to α_0 and $4'\ 58''.9$ to be subtracted from δ_0, the results being $\alpha' = 7^h\ 17^m\ 14^s.62$ and $\delta' = +38°\ 58'\ 10''.8$. These are only approximately correct, since the annual precession for a given star changes from year to year, but they are sufficiently accurate for the computation of the correct precession. Looking at the formulæ to be used,

$$\alpha = \alpha_0 + [m^s\ (t - t_0)] + [n^s\ (t - t_0)] \sin \alpha' \tan \delta'$$
$$\delta = \delta_0 + [n''\ (t - t_0)] \cos \alpha'$$

we see that we shall need the trigonometric functions sin α' and cos α'. In order to get these from the ordinary tables we must convert α' from time into arc, which we do by multiplying by 15. The result is $\alpha' = 109°\ 18'\ 39''.3$. The quantities $m^s\ (t - t_0)$, $n^s\ (t - t_0)$ and $n''\ (t - t_0)$ we take from the table headed $t = 1894.0$ and the line which has 1800 in the column t_0. In explanation of these we can only say that $(t - t_0)$ is the interval 94 years, and m and n are constant for all stars at a given epoch, but vary slowly from year to year. The superscripts indicate that the number is in the one case seconds of time, in the other seconds of arc. The computation will be carried out most conveniently in the following form:

Reduction of Star Lalande 14401 from 1800.0 to 1894.0.

α_0 (1800.0) =	$7^h\ 13^m\ 57^s.27$	$n^s(t - t_0) \sin \alpha' \tan \delta'$ =	$+\ 1^m\ 35^s.950$
δ_0 " =	$+\ 39°\ 03'\ 09''.7$	$m^s\ (t - t_0)$ =	$+\ 4\ \ 48\ .741$
		α_0 =	$7^h 13^m 57^s.27$
Reduction to 1847	$\Delta\alpha + 3^m\ 17^s.35$		
	$\Delta\delta - 4'\ 58''.9$	α (1894.0) =	$7^h 20^m 21^s.96$
α' (1847.0) =	$7^h\ 17^m\ 14^s.62$		
=	$109°\ 18'\ 39''.3$	$\log [n''\ (t - t_0)]$ =	3.275386
δ' " =	$+\ 38°\ 58'\ 10''.8$	$\log \cos \alpha'$ =	9.519427n—10
		$\log [n''(t - t_0) \cos \alpha']$ =	2.794813n
$\log [n^s\ (t - t_0)]$ =	2.099295	$n''\ (t - t_0) \cos \alpha'$ =	$-\ \ 623''.5$
$\log \sin \alpha'$ =	9.974851 — 10	=	$-\ \ 10'\ 23''.5$
$\log \tan \delta'$ =	9.907899 — 10	δ_0 =	$+\ 39°\ 03'\ 09''.7$
Sum =	1.982045	δ (1894.0) =	$+\ 38°\ 52'\ 46''.2$
$n^s\ (t - t_0) \sin \alpha' \tan \delta'$ =	$+\ 95^s.950$		H. C. W.

58. What proportion does the light that is reflected from the eight surfaces of the four lenses of a telescope sustain to the light that is transmitted to the eye? W. E. S.

59. How much light is saved by having the two lenses of an objective cemented together? W. E. S.

These queries are referred to Mr. J. A. Brashear who is now giving a series of articles on the structure and care of the telescope, and who will soon discuss the points involved.

60. What magnitude nebula or comet ought to be seen in a three-inch objective and direct vision? I notice that you say on page 421 of the May, 1894, number of POPULAR ASTRONOMY that Denning's comet was of the 11th magnitude, yet it was a difficult object in your 5 inch finder. Now an 11th magnitude star is easy in a 3-inch, hence the above question.

Answer: In the note referred to it was not the magnitude of the comet but that of its nucleus which was designated as eleventh. The magnitude of a hazy object like a comet or nebula is seldom expressed numerically. Young in his "General Astronomy" gives the following table of minimum apertures with which stars of different magnitudes may be seen:

Star Magnitude	7	8	9	10	11	12	13	14	15	16	17	18
Aperture (inches)	0.4	0.6	1.0	1.6	2.5	4.0	6.3	10.0	15.9	25.1	39.8	63.1

This is based upon the supposition that the aperture of the eye which can just see a sixth magnitude star is 0.25 inch, and that the brightness of a star of any given magnitude is 2.5 times greater than that of the next fainter magnitude.

In practice however observers differ widely among themselves in their estimates of faint stars. Whether an 11th magnitude (as estimated) star is easy or visible at all in a three-inch telescope depends upon the scale upon which the estimate has been made. It may be interesting to compare the numbers in the following table of equivalent magnitudes estimated by four noted observers.

Smyth.		Struve.		Herschel II.		Argelander.
6	=	5-7	=	6.4	=	5.9
6.5	=	6.3	=	7.0	=	6.4
7	=	6.5	=	7.4	=	6.8
7.5	=	6.9	=	7.8	=	7.5
8	=	7.4	=	8.2	=	8.0
8.5	=	7.9	=	8.8	=	8.6
9	=	8.3	=	9.5	=	9.0
9.5	=	8.9	=	10.1	=	9.4
10	=	9.3	=	10.4	=	9.4
11	=	10.0	=	11.3	=	10.0
12	=	10.4	=	11.7	=	10.6
13	=	10.7	=	12.5	=	11.2
14	=	10.9	=	13.3	=	11.8
15	=	10.9	=	14.5	=	12.4
16	=	10 9	=	15.9	=	13.0

61. While studying in Hydra, using Klein's New Atlas and Catalogue, and Webb's Celestial Objects, 4th edition, I tried η Hydræ with a Clark telescope 7½-inch, power 280. I estimated (for I have no micrometer) B = 12 mag.; distance, AB 30″; Angle, AB = 195°. C = 11.5 mag., distance, AC 38″; Angle, AC = 290°. D = 11.5 mag.; distance, AD = 60″; Angle, AD = 165°. Are these values even approximately right? A. E. B.

Answer: A few nights ago I had an opportunity to look at the small stars about η Hydræ and to measure the companions. Your estimates of distance were only about half as great as they should have been. The nearest star is the one mentioned by Webb. The others are so distant that he probably paid no at-

tention to them. I measured the three in order to tell you just what their positions are.

	P. A.	Distance.	Mag.
A B	178°.3	47″.84	4.0 — 10.0
A C	279 .8	74 .51	— 11.0
A D	148 .6	119 .35	— 11.5

No other stars within these distances are visible in the 16-inch telescope.

H. C. W.

62.—I am interesting myself in astronomy, and have an 8½-inch reflector by Brashear. Will you kindly let me know through *Practical Suggestions*, what size refractor would be equivalent to a Brashear reflector of a 12-inch aperture?

L. H. B.

Answer: In answering this query one comes in contact with the personal opinion and prejudice of those who have used only one kind of telescope. Many persons who have used the reflector claim it to be equal, aperture for aperture, with the refractor, while the friends of the refractor claim that the percentage is much lower in the reflector than the refractor. For apertures from 5 to 20 inches the writer thinks that about one sixth more aperture is required for the reflector than the refractor, but this holds good only when the silvered surface is new and the original polish on the glass surface up to the maximum of brilliancy. Perhaps this difference is too great, because, while the general form of modern object glasses gives a minimum outstanding secondary spectrum, the rays are not all brought to the same focal plane, while in a well-corrected reflector, all visible rays are brought to an exact focus. It is true the silvered-glass reflector has a strong selective absorption for the blue and violet of the spectrum, yet all kinds of optical glass have an absorption for some parts of the spectrum, thus practically balancing the absorption in the reflector. Some time the writer hopes to give all this data in this journal, but the above it is hoped will in a measure answer L. H. B.'s query. In the writer's opinion there should be better work done with the reflector in this country than has been done with it, but the instrument requires more care than the refractor, and the owner of a reflector should be willing to study its characteristics and see that it is kept in prime order for the best work. Mr. Edgecomb used to silver his large reflector once every month, and while this is not necessary, the silver surface should not be allowed to become weakened in its reflective power when it is so easy to resilver it.

For photography it is capable of splendid work in astronomical or astrophysical lines, and it is destined to do even greater work in this direction.

J. A. B.

63. I suggest that an article or articles on Celestial photography would be useful to some amateurs. Some hints on the relation of the guiding telescope to the photographic telescope would be especially useful to me. On a 9½-inch reflector like mine, it is difficult to put a guiding telescope of more than 30 or 35 inches focus with 2½ or 3 inches aperture, and the question is if that would be of any help even with a fairly high power and using expanded star disks. Mr. Brashear thinks a 30-inch would work. If you know of any one using such a combination I would like to know the address. W. DEARDEN.

TRINIDAD, COLO.

Answer: We do not know of the combination spoken of. Possibly some of our readers do. If so, kindly give the information. Mr. Brashear will doubtless soon reach the other points of the query in his articles on the structure and care of the telescope. He is doing much in the line of the photographic telescope.

64. Can any one in this country furnish papers or magazines with a translation from a foreign publication and not infringe on copyright? W. W. A.

Answer: This is constantly being done, and we are not aware that the practice is in violation of existing treaty or other relations with any foreign countries.

65. Should a lens be kept in a perfectly dry place? What material should be used in cleaning the object glass? A. K.

Answer: I have asked Mr. Brashear to bear these and a number of similar queries in mind while writing about the care of the telscope in his forthcoming papers.

66. Which would be the more satisfactory for general observation, a 3-inch objective of the highest class (Alvan Clark or J. Byrne) or a 3½-inch of a cheaper class. I find I can get either size of the respective kinds for the same cost. J. W. G.

Answer: Always get the best. A good observer never wants to use a second class telescope.

GENERAL NOTES.

Our readers will be interested, and we hope, pleased, with the fine frontispiece of this number. It is chiefly due to the thoughtful aid extended to us by Mr. Percival Lowell, Director of Lowell Observatory, Flagstaff, Arizona. The article it accompanies is the first of a series that promises much useful information about the planet Mars.

In regard to the continuation of the excellent series of Poole star maps now being published, our readers are referred to the publisher's notices on the same page with the map at the end of this number. We are sure that the entire series of maps will be wanted by many teachers and students of astronomy when their real value is known.

Some of our careful readers have been somewhat perplexed to understand how it is possible for the path of the Moon to be always concave towards the Sun, since it makes revolutions around the Earth during its annual circuit with the Earth around the Sun. In order to make the matter very clear we have prepared a figure showing the path of the Moon with reference to the Earth and Sun during one whole lunation. We are sorry we have not space to give it this month. It will appear next time.

Gales Comet (*b* **1894**).—My first observation of Comet *b*, 1894 (Gale) was obtained on the evening of April 29, 1994. Although near the horizon it was a very fine object in the 3-inch. It appeared round, about 15′ in diameter, with strong central condensation and no tail. At none of my observations of it was a tail or distinct nucleus seen, although a nucleus was suspected on several occasions. My observations of May 1st placed it of about the third magnitude, it appeared then to the naked eye nearly equal in brightness to that of a third magnitude star. W. E. SPERRA.

Eruptive Solar Prominence (June 7, 1894).—The following account of an eruptive prominence observed here last evening (June 7th), may be of interest.

About 5:15 P. M. having finished an observation of the Sun for sun-spots and faculæ I adjusted the spectroscope to the telescope and commencing at the N. limb examined the circumference of the Sun around by the W. and S. towards the E. for prominences, with the slit tangential to the limb. On reaching the S. E. limb I noticed an intensely brilliant large prominence in the C line, and upon opening the slit observed a group of very bright "spikes" and "flames" which seemed to be in violent disturbance, as when I attempted to make a rough pencil sketch of it I found it was changing so rapidly that it was impossible to correctly delineate it. I opened the slit fully 1-32 of an inch, which at the focus of my 3-inch telescope would represent about 70,000 miles, and I could trace the height of the prominence nearly the entire distance; it was also bright and distinct in D_3 and F.

Fig. 1.

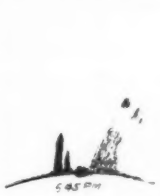


Fig. 2.

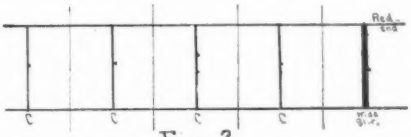


Fig. 3

I left the telescope now and returned in about 10 minutes and was astonished at the change which had taken place. Figure 1 represents the disturbance as near as I could sketch it when I first observed it at 5:25 P. M., and figure 2 its appearance at 5:45 P. M. When I returned the fine "spikes" had almost disappeared-but a few faint flames remaining, and a bright mass of "debris" which rested partly on and within the limb. With a narrow slit the C line was noticed to be shifted much towards the blue, indicating a rapid approach towards us in the line of sight. At 6:00 P. M. but little remained of this great disturbance, but turning my attention farther in on the disc I found that the entire region from the limb where the prominence was, to the western portion of the group of sunspots which was about 2 days in, to be in a violent state of agitation; a prominent spot of faculæ was on the S. E. limb and faculous area surrounded the sunspots mentioned. At numerous points in this region the C line appeared as in the sketches, one or more dark vibrating tongues or blow-pipe looking jets adhering to the line directed towards the red end of the spectrum. These persisted even when the slit was gradually opened, until with a wide slit they appeared as dark points in the brighter opened space. Observation ceased at 6.10 P. M. It would be interesting to know at what time these paroxysms first began and what if any effects were noted in the Earth's magnetism.

DAVID E. HADDEN.

ALTA, Iowa, June 8th, 1894.

Bright Meteor.—May 25, 9 P. M., a beautiful meteor, as bright or brighter than Venus at her brightest, and of a yellowish red color, appeared above and east of Regulus and disappeared near Pollux. It had a beautiful train of fusiform shape and lasted only a moment.

W. E. SPERRA.

Visualizing the Earth's Motion.—The recent articles in POPULAR ASTRONOMY on this subject recall some experiments made by the writer several years ago for a similar purpose.

It is well known that all objects on the Earth's surface in intermediate latitudes have a skewing or twisting motion when compared with a point on the celestial sphere—a star for example just above the horizon in the north. The south end of a street, or house, is moving more rapidly toward the east than the north end.

In view of this fact it occurred to me that a horizontal bar placed in the plane of the meridian and properly poised on a pivot, or suspended by untwisted fiber, would show this motion. A bar so placed and pointing toward the star on the northern horizon would continue to point toward the star and would follow it as it moved eastward if all rigid connection with the Earth was removed, and it was freely suspended and undisturbed.

The experiment was successfully performed with a poised bar—a sketch of which I give below.

I used a straight bar of wood 9½ feet long and ⅞ of an inch square, with a 1½ pound weight upon each end, and stayed with brass wire as shown. The needle upon which it was poised is shown at N. The block in which the needle is placed is in two parts, one of which is made fast to the framework and a slight groove cut across its center perpendicular to the bar, in which to place the needle. The two pieces are held together by screws and this firmly holds the needle.

A movement of one inch, as shown by the pointer at one end of the bar, over a divided scale, will = 1° — for this length of bar.

The success of the experiment depends almost wholly upon the needle point and the surface upon which it rests.

A darning needle was placed in a jeweler's lathe and its extreme point slightly rounded with a fine hone. It was then tempered very hard, burnished, and highly polished, and was touched with watch oil when used. The needle rested upon the flat, smooth surface of a small diamond also highly polished and firmly soldered in a brass plate. This rested upon a support which passed across the bar and beneath the needle point.

This support was raised a few inches from the floor and leveled up so the needle point would remain near the center of the diamond, as any contact with its mounting would be fatal to success.

My experiments were conducted on the cement floor of a small room in the basement, all the openings being carefully closed to prevent air currents, and I remained very quiet while watching the index, but with great interest as I still remember it.

If there was no friction or atmospheric resistance, the movement would be a little more than 9° for the first hour in this latitude, + 40° 14′. Below I give some of the results as taken from a record made at the time.

Oct. 5th, 1883, set the instrument at $12^h\ 24^m$ P. M., went to dinner and returned at $1^h\ 19^m$; it had moved 6° in 54^m.

Moved the index back with tip of handkerchief, and when it became steady commenced to note its motion from

h	m								Time for each degree	
1	29	P. M.								
1	37		moved	1°		in	8m		8m	
1	46		"	2		"	17		9	
1	55	30	"	3		"	26	30s	9	30s
2	05	30	"	4		"	36	30	10	
2	15		"	5		"	46		9	30
2	24		"	6		"	55*		9	
2	29		"	6	30′	"	1	00		
2	33	30	"	7		"	1	04	30	9	30
2	43		"	8		"	1	14		9	30
2	53	30	"	9		"	1	24	30	10	30
3	03	30	"	10		"	1	34	30	10	
3	14		"	11		"	1	45		10	30
3	26		"	12		"	1	57		12	
3	29		"	12	15	"	2	00			
3	37		"	13		"	2	11		11	

* Nearly the same as the first experiment.

I. B. PENCE.

A Convenient Naked-Eye Star Atlas.—Permit me to call the attention of the readers of POPULAR ASTRONOMY to a very compact, clear and inexpensive star atlas for naked-eye work or reference, which may not generally be known.

Its title is "Himmels Atlas, by Richard Schurig, Leipzig," and it can be imported through Messrs. B. Westermann & Co., Box 2306, New York, N. Y., at a cost of about one dollar.

It comprises eight double star maps, each map occupying two pages, and includes all the naked-eye stars from the north to the south pole.

The rectangular or non-polar maps, have a range of 120° in R. A. and 80° in Decl.

The sizes, or magnitudes of the stars, are extremely well graded, the brightest stars being rather large and sufficiently so as to allow, in general, subdivisions into thirds of magnitudes in the scale, without making the faintest, or 6⅓ magnitude stars, too small.

The names and divisions of the constellations also appear on the maps.

Still another recommendation is the fact that the right ascension is given in time as well as degrees.

The size of the atlas is about 13 inches by 9 inches, being of octavo form, and it is bound in paper covered boards, so that it is very convenient and portable, being more so than the folio maps.

For convenience in identifying stars by night, it is hardly surpassed by any atlas with which I am acquainted, while its low cost brings it within the reach of every one.

O. C. WENDELL.

Harvard College Observatory, July 14, 1894.

Photographs of the August Meteors.—During the August Meteor shower photographs were being made with the Willard lens (6 in. 31 in.) and meteors were photographed on three nights—Aug. 9th, 10th, 11th.

The exposure of the 9th was in the region of the meteor radiant. On this plate three meteors are shown. One, a fine large one, is almost stationary, the trail being about 1-10-inch long = about 12′.

On the 10th the exposure was in the region of γ Sagittæ, and one meteor was secured. That of the 11th had Vega central and another meteor was caught on this plate.

The display this year was fine and abundant.

E. E. BARNARD.

Mt. Hamilton, 1894, Aug. 14.

BOOK NOTICES.

Scheiner's Astronomical Spectroscopy.—This book is a treatise on astronomical spectroscopy, and is a translation of *Die Spectralanalyse der Gestirne* by Professor Dr. J. Scheiner of the Royal Astro-Physical Observatory at Potsdam. The translation from the German, revision, and enlargement were done by Edwin B. Frost, assistant professor of Astronomy at Dartmouth College, with the coöperation of Dr. Scheiner. Messrs. Ginn & Company of Boston and Chicago are publishers. pp. 482. Price $5.00.

In our opinion, this is by far the best book on its theme in the English language. It is written by scholarly men, and yet they have handled their themes so well that any person with very moderate attainments in science will read nearly all of it easily. For those who know but little about practical spectroscopy it will prove most exhilarating and fascinating. In this book spectroscopic apparatus is explained, spectroscopic theories are discussed, and the results of spectroscopic work are admirably shown. We now only call attention to this very important new book. In the next number of ASTRONOMY AND ASTRO-PHYSICS a fuller notice will be given.

Wilson's Cyclopædic Photography is a hand-book of the terms, processes, formulæ, and appliances available in photography. It is arranged in the form of a cyclopedia for ready reference. Its author and publisher is Edward L. Wilson, Ph.D., editor of "Wilson's Photographic Magazine," 853 Broadway, New York. It is printed in clear type with heavy-faced titles and is fully and well illustrated and seems to cover the ground of the photographic art in the way of a reference book excellently well.

College Algebra, by Edward A. Bowser, L. L. D., 4th edition, published by Messrs. D. C. Heath & Co., Boston, pp. 540.

Plane and Solid Geometry, by the same author, and publishers, pp. 393.

Analytic Geometry, by the same author, and published by the D. Van Nostrand Company, New York. 1894, 18th edition, pp. 305.

From our experience in the use of some of them the Bowser text-books are among the best for the class room, because they wear well. And one thing why they have staying qualities is the fact (which teachers do not always fully realize) that the student has to do something to get on with his work. The problem and example work required of the student is the all important factor in real student progress. A teacher may tell the student never so plainly, may work out examples in illustration of principles very freely, and yet not at all reach the need, the student's need for a working and real thinking knowledge of the thing he is trying to impart. Be not of those who *say* and *do not*, but the student *must* say and *do* for himself. This is one thing why Bowser is successful and why his books have gained an enviable reputation in the schools generally.

The College Algebra is full in its range of matter, it has good order, apt illustration, clear statement, most needful parts amply developed, *e. g.*, factoring and pages of examples to the wish of the most fastidious teacher. Teachers who have not seen this book, may well examine it.

The Plane and Solid Geometry is also a late book having passed to its 3rd edition. Its demonstrations are concise, depending largely on symbols which are wisely now the modern fashion, if the symbolism is not overdone. It avoids this on the one hand, and, on the other, is not so brief or concise as to be obscure. Some late, otherwise good and popular, texts on this branch have sacrificed principle by the use of brevity. It is not proof of a proposition that establishes the converse instead of the proposition itself. I have not noticed that error in Bowser. The figures are good, the exercises are abundant and the publisher's part substantial.

PUBLISHERS' NOTICES.

Volume II of this publication begins with the present issue. Its plan in general is the same as last year. Some of our past able writers and other new ones of marked prominence will contribute to it. Each number will contain not less than 48 pages of reading matter, printed on a good quality of book paper, and illustrated with engravings and plates of superior art adapted to the themes under discussion.

Advertising space in Vol. II may be secured through the publisher. Send for card showing rates. Correspondence is solicited.

Former subscribers are earnestly solicited to aid us in extending our circulation. With your thoughtful help the general subscription list may be doubled, and the magazine itself greatly improved.

Vol. I, completed in June last, consists of 500 pages of articles on modern astronomy, current celestial phenomena, late discoveries, queries with short answers, and practical suggestions, furnished generally by astronomers of known authority, at home and abroad. It contains eighty illustrations of astronomical themes, one-third of these being full-page engravings. The volume as a whole, with its full indexes, is a book of reference on current astronomy which ought to be useful in *any general* library.

Vol. I complete, in pamphlet form, will be sent to any American address for $2.50. To foreign countries for $3. Orders should be made promptly, as not a large number of copies have been kept.

The office supply of Nos. 1 and 2 (Sept. and Oct., '93) has been so reduced that we wish to recall a considerable number of copies of these issues, and shall be glad to pay full price (25 cents) for any which are returned to us in good condition. At present we cannot sell these numbers except in the full sets of Vol. I.

Poole Bros. Celestial Planisphere may, perhaps, be best described as an abjustable map of the heavens, on which all the constellations visible at a specified hour of any given day in the year are clearly indicated; and by which, also, the time that a given star rises, sets, or passes the meridian on any given day of the year can be immediately ascertained. It consists of a movable disk, 19½ inches in diameter (on which are shown nearly all the stars visible to the naked eye, and the principal nebulæ from the polar star to the 50th degree south of the equator), attached by a pivot to a heavy cardboard back, rectangular in shape, 18¾ x 23 inches. The outer edge of the disk is divided into equal parts representing the days and months of the year. Over this disk is a fixed frame, the outer circle of which is divided into equal parts representing the hours and minutes of the day, while the edge of the lower inner opening represents the circle of the horizon. By moving the disk so that a given day of the year (as represented on its outer edge) corresponds with the hour and minute (as represented on the fixed frame) for which the observation is desired, all the stars visible at that time will be included in this opening. By an equally simple adjustment, the time can be ascertained when any star rises, sets, or passes the meridian on a given date.—*From Poole Brothers Circular.*

MAP OF THE

CONSTELLATIONS

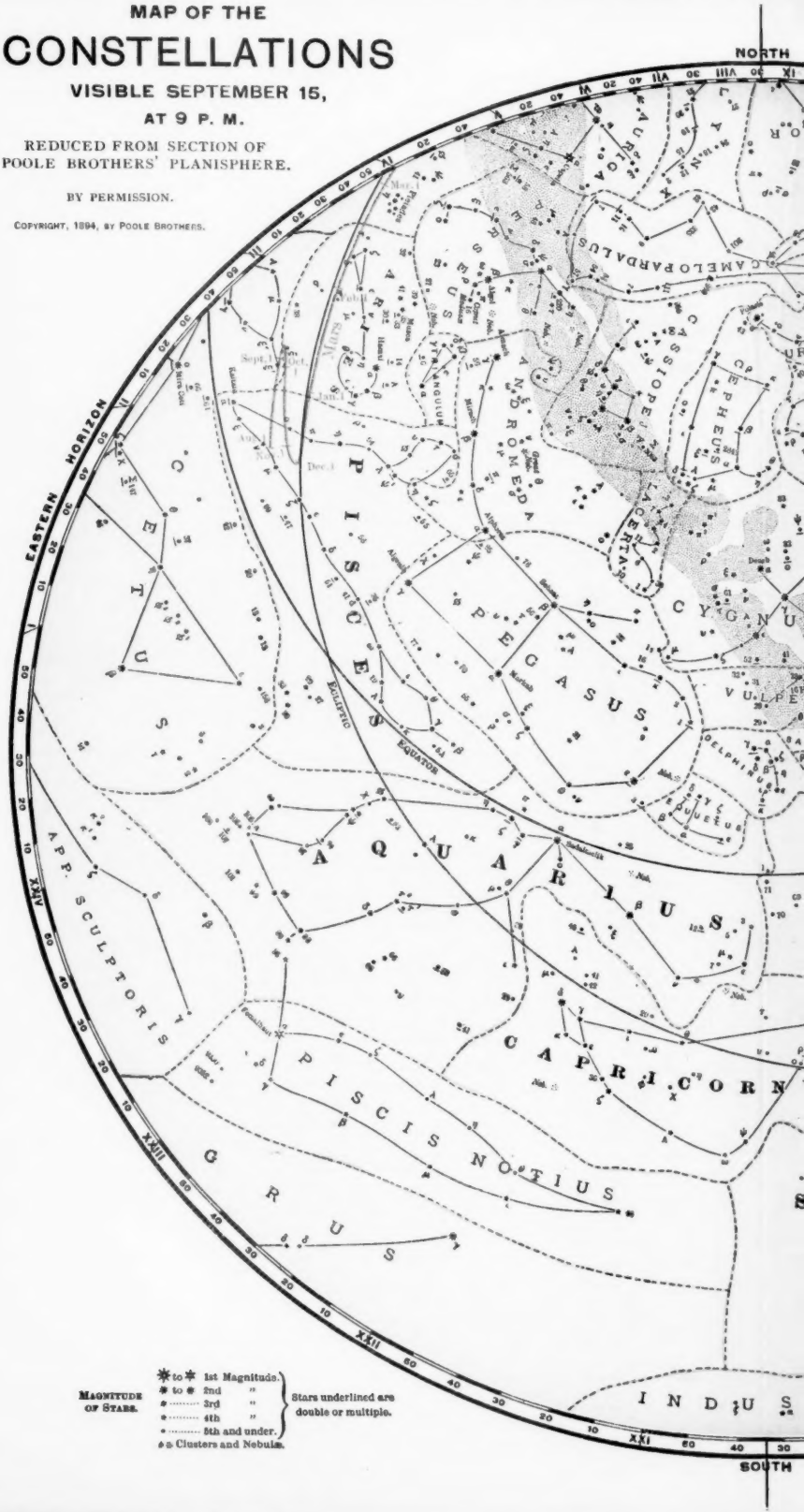
VISIBLE SEPTEMBER 15,

AT 9 P. M.

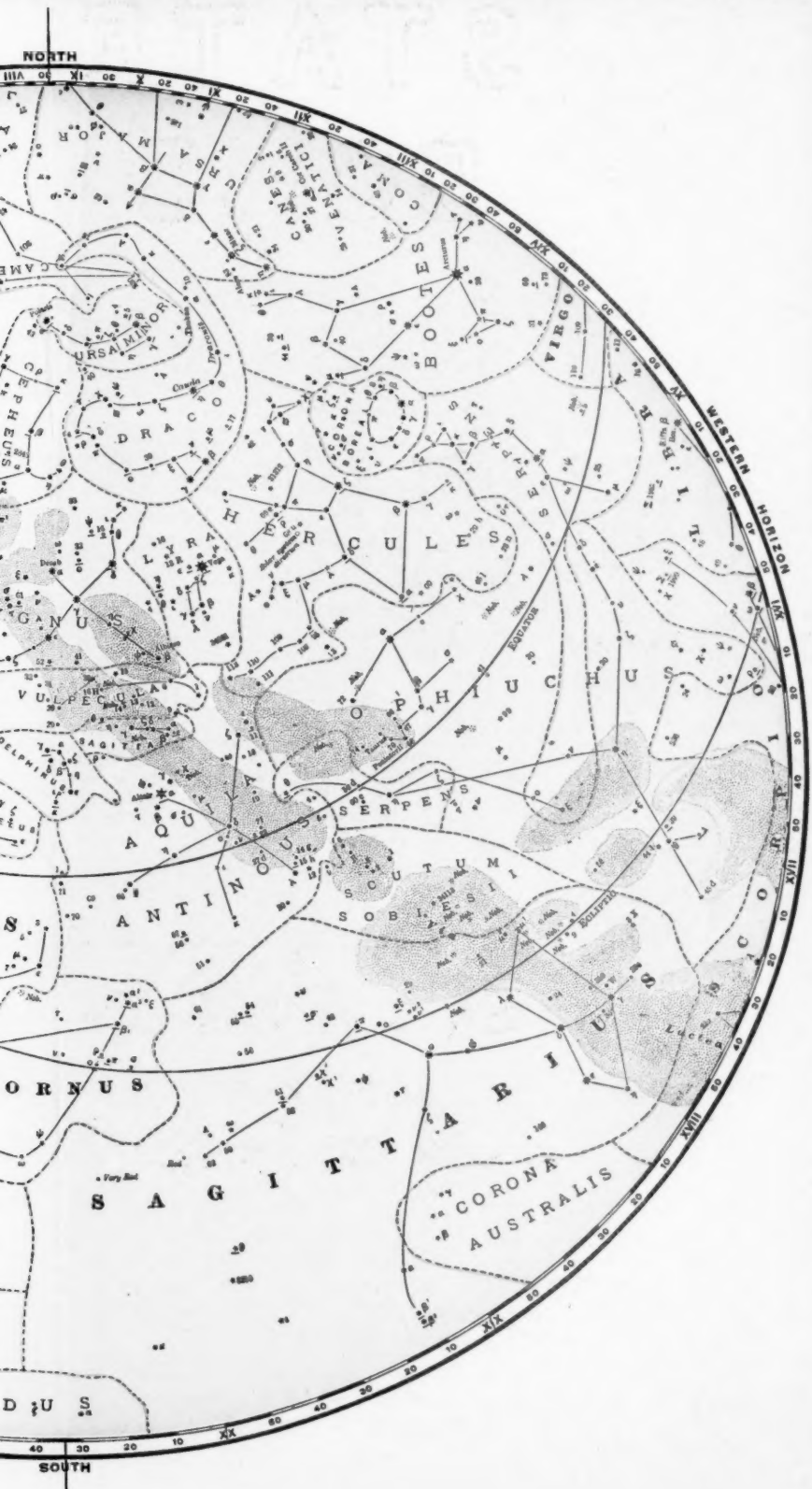
REDUCED FROM SECTION OF
POOLE BROTHERS' PLANISPHERE.

BY PERMISSION.

COPYRIGHT, 1894, BY POOLE BROTHERS.



MAGNITUDE OF STARS.			
✱ to ✱	1st Magnitude.	Stars underlined are double or multiple.
✱ to ✱	2nd "	
✱	3rd "	
✱	4th "	
✱	5th and under.	
⊕ ⊜	Clusters and Nebulæ.	


NORTH
WESTERN HORIZON
SOUTH
URSA MINOR
DRACO
CEPHEUS
CAMELOPARDUS
CASSIOPEIA
CANES VENATICI
COMA BERENICES
BOOTES
VIRGO
LIBRA
HERCULES
LYRA
CYGNUS
VULPECULA
SAGITTA
AQUILA
OPHIUCHUS
SERPENS
SCUTUM
SOBIESI
ANTINOUS
CAPRICORNUS
SAGITTARIUS
CORONA AUSTRALIS
Equator
Ecliptic